FRDA REPORT 043

REGENERATION DELAYS AND NATURAL YIELDS ON UNTREATED BACKLOG FOREST LAND IN BRITISH COLUMBIA

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August 1988

This report has been reviewed by the British Columbia Ministry of Forests and the Canadian Forestry Service and approved for distribution. Approval does not necessarily signify that the contents reflect the views and policies of the British Columbia Ministry of Forests or the Canadian Forestry Service. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

ISSN 0835-0752

Canadian Cataloguing in Publication Data

Smith, Stephen M.
Regeneration delays and natural yields on
untreated backlog forest land in British Columbia

(FRDA report, ISSN 0835-0752; 043)

Issued under Forest Resource Development Agreement.
Co-published by B.C. Ministry of Forests
On cover: Canada/B.C. Forest Resource Development Agreement
ISBN 0-7726-0862-X

1. Forests reproduction - British Columbia. 2. Conifers - British Columbia
Seeds. 3. Conifers - British Columbia - Growth. 4. Forest management - Briti
Columbia. I. Stephen Smith and Associates Forestry consultants. II. British
Columbia Ministry of Forests. Industry Development and Marketing Branch.
III.Pacific Forestry Centre. Economic Analysis Section. IV. CanadianForstry
Service. V. British Columbia. Ministry of Forests. VI. Forest Resource
Development Agreement (Canada). VII. Canada/B.C. Forest Resource Development
Agreement. VIII. Title. VIII. Series.

SD391.S66 1988 634.9'56 C88-092187-0

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BACKGROUND

The five-year $300 million Canada-British Columbia Forest Resource Development Agreement (FRDA) was launched in 1985 to enhance B.C.'s forest base and strengthen its job creation potential. In B.C. there are about 1.36 million hectares of land not satisfactorily restocked (NSR). Over the last five years NSR has been estimated to be accumulating at a rate of 59,000 ha per year. A major objective of FRDA is to manage part of the backlog of non-satisfactorily restocked lands. To achieve this objective a large program of backlog reforestation is being implemented on both a cost shared and unilaterally funded basis.

At some point, the impact of this program will be evaluated. To do so will require estimates of the yield from untreated backlog areas and yields from treated backlog areas. This report provides estimates of the expected yields from untreated backlog areas.

PROJECT OBJECTIVES

The objectives of this study are to:

(1) review available studies and information regarding the growth and yield of land which has restocked naturally;

(2) discuss biological factors which influence the delay of natural restocking and yields from naturally restocked land;

(3) identify alternative methods to estimate growth and yield of backlog land, if left to restock naturally;

(4) develop estimates of growth and yield which would reasonably be expected from untreated backlog forest land.

ESTABLISHMENT OF NATURAL REGENERATION

INTRODUCTION

This review is concerned with the establishment of forest from natural regeneration after clear-cut logging.

There are three components of stand establishment from natural regeneration. These are:

- seed source
- seed dispersal
- seedling establishment

SEED SOURCE

After clear-cut logging, coniferous seed may be supplied from windborne seed from the adjacent standing timber, or from cones in the logging slash.

Conifers do not produce a good cone crop every year. Garman (1955) gives a crop record over a 24 year period for some Douglas fir (Pseudotsuga Menziesii), grand fir (Abies grandis) and western white pine (Pinus monticola) trees at Cowichan Lake. These trees were between 40 and about 100 years old. In eight of the 24 years the Douglas fir and grand fir had good cone crops (at least 50% of the trees bore cones). In the same period white pine produced only two good crops. The different species did not always produce their big crops in the same years but in nine seasons cone-bearing was ineffective on all three species. The same study suggests that old growth Douglas-fir trees bear seed less frequently than the 60-100 year group. It has been found (Toumey and Korstian (1959)) that western hemlock bears seed more frequently than Douglas-fir. When cones are produced, in many species the seed ripens in the fall.

The B.C. Ministry of Forests and Lands (MOFL) (1984) gives the cone crop periodicities shown in Table 1 for major tree species in B.C.

Table 1: Approximate Cone Crop Periodicity of Major Species in B.C.

Species	**Frequency of Good Collectible Crop (Years)**	
	Low elevation/dry	**High elevation**
Douglas Fir	5	10
Sitka Spruce	3	6
Interior Spruce	7	12
Lodgepole Pine	3	5
Western Hemlock	4	8
Western Red Cedar	2	4
Ponderosa Pine	2	5
Larch	5	6
True Firs (Balsam)	3	3

After clearcutting, the trees at the forest edge provide the source of windborne seed. Cones in the slash may provide a second source of seed. Lodgepole pine cones in the slash need heat from a burn before they will open quickly. Without burning the seed is released in reduced quantities over a period of years.

SEED DISPERSAL

Different species and different climates affect the timing and pattern of seedfall. In a study of stands in the Northern Sierra Nevada of California, McDonald (1983) observed the seedfall over four years in mature stands of ponderosa pine (*Pinus ponderosa*), Douglas-fir, incense cedar (*Libocedrus decurrens*) and California white fir (*Abies concolor*). Most seeds were distributed in the fall on days when winds were from the northeast and the atmosphere was warm and dry. When warm temperature and low humidity combined to lower the moisture content of cones and scales, a shower of seeds took place. If this weather continued, most of the seeds fell, often within a week. If this weather did not last long enough the remaining seeds dribbled out between storms. In coastal British Columbia, Garman (1955) found that most of the seedfall from Douglas-fir, western red cedar (Thuja plicata) and grand fir fell during the months September to December. The seedfall from grand fir and western red cedar was faster than that from Douglas-fir. Hemlock (Tsuga spp.) was much slower in releasing its seed. Hemlock seed fell from September to July.

The distance seed will travel on the wind depends on seed weight, wind speed, topography and the efficiency of seed wings. Smith (1944) refers to a study by Siggins (1933) which showed that Douglas-fir seeds fell to the ground 1.7 times as fast as hemlock seed. Western red cedar fell to the ground nearly twice as fast as hemlock. Hemlock seed will travel further from the margin of a clearcut than Douglas-fir or cedar. In California it has been found that most sound seeds are dispersed within a distance of one half to two times the average height of the dominant and co-dominant trees. (McDonald (1983), Barrett (1966), Curtis and Foiles (1961), Fowells and Schubert (1956), Roy (1960).) The effect of local winds and slope can change the distance over which seed travels. For example, Smith (1944) refers to Godwin (1932) who found on the East coast of Vancouver Island that satisfactory restocking could occur up to 300 metres from the uncut edge in the direction of the prevailing winds. In the opposite direction satisfactory reproduction rarely extended beyond 150 metres from the timber edge.

Hetherington (1961) studied the dissemination of seed from western hemlock (Tsuga heterophylla), western red cedar and Amabalis fir (Abies amabalis) on the West coast of Vancouver Island.

The first seedfall of all species occurred at approximately the same time, but the subsequent pattern varied. Seed of all species could be expected to fall any time after mid-September but the actual time was dependent upon the prevailing weather conditions. The majority of balsam seedfall occurred early in the season and was more or less complete by the following February. Heavy falls of hemlock and cedar seed continued until March.

The amount of hemlock and cedar seed approached a minimum value at approximately 400 feet from Eastern margins and 160 feet from other margins. Most balsam seed fell less than 90 feet from the margin.

Atmospheric humidity was a major factor in the dissemination of seed of hemlock and cedar but not balsam fir. Periods of heavy seedfall were strongly correlated with periods of low relative humidity. In this study on Western Vancouver Island, low relative humidity coincided with dry Easterly winds. In fact, 96% of hemlock and cedar seedfall occurred during easterly winds. The intensity of balsam seedfall was related more to wind strength and duration than to direction. This was because Balsam cones disintegrate on the trees, a mainly mechanical process accelerated by strong winds.

SEEDLING ESTABLISHMENT

Not all seeds falling onto the ground will germinate. Considerable loss in numbers of potential trees takes place when dormant seeds die or decrease in germination capacity. This may happen from attacks by fungi, insects, birds, frost, fire and small animals like deer mice. Both Garman (1955) and McDonald (1983) describe the effect of deer mice (Peromyscus maniculatus) populations on the number of viable seeds. The populations of deer mice that congregate on cut-over lands are higher than those in the forest and they are by far the greatest hazard to disseminated seed of Douglas-fir. Tests have shown that, when other food is scarce, one mouse consumes over 270 Douglas-fir seeds per day (Garman 1955)). McDonald (1983) says that populations of deer mice in mature forests of the Sierra Nevada are relatively stable at about 12 mice per hectare. Clear-cuttings, however, produce environments favorable as mice habitats. Supplies of seeds and other foodstuff become abundant and new areas for shelter and reproduction are provided. As mice increasingly reproduce and immigrate into clearcuttings, populations rapidly expand.

Slash fires in the fall destroy a significant amount of the seed which has been dispersed.

Vaartaja (1954) studied the effect of environmental factors on seed and seedling survival. Seed of Pinus sylvestris was subjected to temperature variations which simulated those on exposed forest sites. This seed lost some of its germinative capacity in the first five days. Seeds of Pinus sylvestris, Picea abies, Betula verrucosa and B. pubescens tolerated exposure to drought very poorly if germination was advanced enough to show a radicle tip.

Only a small fraction of the seed produced survives to germinate and a further fraction of the germinates survive to become established seedlings. Regeneration of a logged area depends upon a favorable combination of many variables of climate and site. In general, the soil and weather conditions necessary for satisfactory germination are more readily obtained than conditions favouring survival. The seeds of wind-disseminated species usually germinate best on or slightly beneath the surfaces of seedbeds that tend to remain moist. Bare mineral soil is usually the best seedbed for such species. Seedbeds of horizontally oriented materials, such as coniferous litter tend to be unfavorable because they inhibit penetration of seeds into moist substrata. Delays in germination are dangerous because they lengthen the period of exposure to birds, insects and rodents. Losses from germination failure, which are often caused by the drying out of seedbeds, may be more serious than losses of germinated seedlings.

Once successful germination has taken place, new seedlings are most vulnerable during the first few weeks of their existence, while their stems are still green and succulent (Smith (1962)). Heat injury resulting from extremely high temperatures on surfaces exposed to direct solar radiation takes a heavy toll among conifers. Tender seedlings in shaded situations are subject to damping-off caused by a wide variety of weakly parasitic fungi that are normally saprophytic and incapable of attacking larger seedlings. Cutworms and other insect larvae are particularly active during this period. Seedlings that germinated late and remained succulent in the fall are commonly killed by frost. The dangerous succulent period ends when the outer cortical tissues of the stem become dry and straw coloured, a process referred to as 'hardening.' Thereafter, the attrition of various damaging agencies continues, but the period of catastrophic losses is generally at an end.

Drought is distinctly different from heat injury and is as likely to take place after the succulent stage as during it. It will not occur if seedling roots extend themselves rapidly enough to maintain contact with portions of the soil where water is available.

Given a good seed supply, when seeds fall on a clearcut area, the number of small niches favorable to initial seedling establishment strongly affects the success of natural regeneration. The effect of these micro-environments is controlled by (1) amount of overhead cover, (2) proximity to competing vegetation, (3) physical characteristics of the seedbed. Other vegetation on the site provides favorable and unfavorable effects. The less vegetation left on the site, the less competition will be and the greater the amount of light, soil moisture and nutrients available to the regeneration.

On the other hand, exposure of the ground surface increases the risk of damage to seedlings from extremes of temperature. The following account of this risk is based on Smith (1962). The air within several inches of the soil surface is held virtually motionless because of friction. Radiant energy enters and leaves this stratum freely but the transport of heated air into and out of it depends mostly on wind-induced turbulence and is very sluggish. The vertical movement of heated air, as well as water vapour and carbon dioxide, results largely from the chaotic movement of 'clumps' of gas molecules in little swirls and eddies embedded in successively larger swirls and eddies. The net effect is to move heat, water, carbon dioxide and various materials from strata where they are present in abundance to those where they are less abundant. This 'turbulent transfer' is vastly more efficient in air than monomolecular processes like heat conduction and diffusion. The rate at which it proceeds depends on the extent to which the wind penetrates the thin stratum above the surface.

If direct sunlight reaches the ground, the surface becomes remarkably hot and the air is strongly heated from below. Lethal temperatures (50 degrees Centigrade and higher) may be attained depending on the rate at which heat is transferred downward by conduction in the soil and upward by turbulent transfer. If the ventilation is poor, as in a small opening surrounded by trees, unprotected succulent seedlings are swiftly killed by heat injury even though they may be well supplied with water. The heating effect is accentuated if the ground is covered by litter which insulates the mineral soil and restricts downward conduction of heat.

At night the net flow of heat is reversed. Surfaces are cooled by radiation to the sky and the heat losses are replaced only by upward conduction of heat from the soil and downward movement of warm air by turbulent transfer. If the air is initially cool and dry (dewpoint below zero degrees Centigrade), succulent shoots are likely to be damaged by frost. The cooling is also slowed by re-radiation of heat back to the surface from any surrounding trees that block the outgoing radiation. Frost damage is most severe in the centres of openings where there is the least return of heat by re-radiation. Heat injury, however, is most likely along the sunlit northern edge (i.e. south aspect) of a forest opening and virtually impossible along the shaded southern margin.

In very small openings, the development of extremes of surface temperature is impeded by side shade; in large openings, the wind causes enough turbulent transfer of heat to restrict the diurnal range of surface temperature. There is evidence that the greatest extremes of temperature occur when the diameter of an opening is one and a half times the highest of the surrounding trees. Presumably this is the situation in which the combined effect of side shade and ventilation is the least.

The other basic factor affecting regeneration from seed is the physical nature of the forest floor. The most important kind of physical difference is between bare mineral soil and surfaces composed of litter or other unincorporated matter. Mineral soil is a much more stable moisture source and comes in closer contact with small seeds than does litter. Under direct sunlight surfaces composed of litter become hotter than those of mineral soil. The thickness of litter determines the crucial distance that seedling roots must penetrate before they reach mineral soil. There are kinds of organic seedbed materials other than ordinary litter. On sites and in regions where decomposition is slow, rotten wood may be a common and favorable kind of seedbed. Living mosses can be very unfavorable or very favorable depending on whether they or newly germinated seedlings grow faster in height.

Lavender et al (1956) carried out an empirical study of Douglas-fir natural regeneration in Oregon clearcuts, logged by high lead methods. They analysed the effect on the percentage of mil-acre plots stocked with one or more seedlings of:

- vegetation cover
- logging slash
- intensity of slashburn
- seedbed conditions
- distance from seed source

Their results applied to forest land areas fulfilling the following conditions.

Size: less than 65 ha

Distance from adjacent timber: less than 500 metres

Years since logging or slashburning: 4 to 11

Elevation and location: 500 to 1250 metres in the east slope of the Oregon Coast Range or the west slope of the Oregon Cascades north of Oakridge.

The study surveyed 13 settings which had not been planted. Three thousand two hundred and forty one mil-acre plots were examined intensively in these settings. Stocking surveys were made using four mil-acre circular plots, each sub-divided into one mil-acre quadrants. The four mil-acre plots were spaced 41 metres apart on lines parallel to and perpendicular to the long axis of each setting. Each line was located 203 metres from adjacent parallel lines.

Their results allowed the development of a simple model to predict the percentage of mil-acre plots stocked with at least one seedling. This model was:

$$Y = M + B + E + S + C_H + C_W + b(d) + g(t)$$

where: Y = % mil-acre plots with at least one seedling
M = a constant
B = intensity of burn
E = aspect class
S = logging slash class
C_H = herbaceous vegetation cover class
C_W = woody vegetation cover class
b = a constant
s = distance from seed source
g = a constant
t = years since logging or burning

In this study elevation did not appear to be a significant factor affecting natural regeneration delay.

Aspect affects the survival of regeneration by affecting the temperature extremes. The amount of woody cover affects regeneration survival by direct competition for light, moisture and nutrients. The amount of logging slash affects the amount of available seedbed. The consultant arbitrarily selected the value of 31% of mil-acre plots stocked with at least one seedling to represent satisfactory stocking. Then the combination of no burn and 203 metres from the seed source was selected as the background condition. Using the coefficient values provided by Lavender et al (1956) and solving their equation for years since logging (regeneration delay) under different conditions shows the variation in regeneration delay. This was done for both north and south exposures as a function of varying the amount of logging slash and percentage woody cover. The results of the consultant's calculations are shown in Tables 2 and 3.

Table 2. Regeneration delays (years) north exposure Oregon Coastal Douglas-fir (based on Lavender *et al* (1956))

Slash Cover %	Woody Cover % 0-33	33-66	66-100
0-25	2	4	6
25-50	3	5	7
50-75	4	6	8
75-100	5	7	9

Table 3. Regeneration delays (years) south exposure, Oregon Coastal Douglas-fir (based on Lavender *et al* (1956))

Slash Cover %	Woody Cover % 0-33	33-66	66-100
0-25	8	10	12
25-50	9	11	13
50-75	10	12	14
75-100	11	13	15

In Tables 2 and 3 the expected regeneration delays range from two to 15 years, depending on the conditions found in each mil-acre plot. On any one setting, a wide range of microsite conditions will be found and a correspondingly wide range of regeneration delays would be expected. Expanding this idea to a larger scale, for every 1,000 hectares logged, some parts might be expected to restock quickly and some more slowly. In fact, it would be possible to construct a table showing the proportion of every 1,000 hectares logged regenerating in one year, two years, etc.

Smith and Wass (1976) collected regeneration data from 9,361 mil-acre plots and point samples along 78 transects distributed widely throughout the Nelson Forest District. The survey was conducted in the West and East Kootenay Regions at elevations ranging from 838 to 1,905 m and on slopes of 30 to 81%. Years since logging varied from zero to 23 years. Sampling occurred in three biogeoclimatic zones: Interior Douglas-fir (IDF), Interior Western Hemlock (IWH) and Engelmann Spruce - Subalpine Fir (ESSF) and in two transitions (IDF/ESSF and IWH/ESSF). Most sampling was conducted in six major logging method/post harvesting treatment combinations:

- summer ground skidding, burned and unburned;
- winter (on snow) ground skidding, burned and unburned;
- summer high-lead, burned and unburned.

General vegetative cover after logging increased steadily with time. Vegetative cover on roads reached about 40% cover for main skid roads and 55% for other roads after 11 years. Vegetative cover on unburned surfaces between roads reached about 72% cover and on burned surface, about 63% 11 years after logging. For burned clearcuts re-surveyed after one year, vegetation cover doubled on and between roads. The percentage increase was much less in unburned clearcuts but, because of a higher residual vegetation component, the cover between roads remained higher than on the burned clearcuts.

The major species of new tree regeneration were Douglas-fir and lodgepole pine (Pinus contorta) in the IDF zone, western hemlock and western red cedar in the IWH zone, and subalpine fir and Engelmann spruce in the ESSF zone. Subalpine fir (Abies lasiocarpa) was the major species of advance regeneration, particularly at the higher elevations. Excluding zero and one year clearcuts, mil-acre stocking levels were highest on roads and between roads inthe IWH zone, and lowest on roads and between roads in the IDF/ESSF transition. Total stocking (new and advance regeneration) was highest on roads and between roads in the IWH zone and lowest on roads and between roads in the IDF/ESSF transition. Particularly in the oldest group of clearcuts, road surfaces had higher stocking levels of new regeneration than areas between roads. Of all surfaces, total stocking was highest on areas between roads in unburned clearcuts. Excluding planting, areas between roads in unburned clearcuts were satisfactorily restocked (over 30% of mil-acre plots with acceptable advance or new regeneration) after about nine years. Surfaces between roads in burned clearcuts remained unsatisfactorily restocked up to 10.5 years, the average age of the oldest group of burned clearcuts.

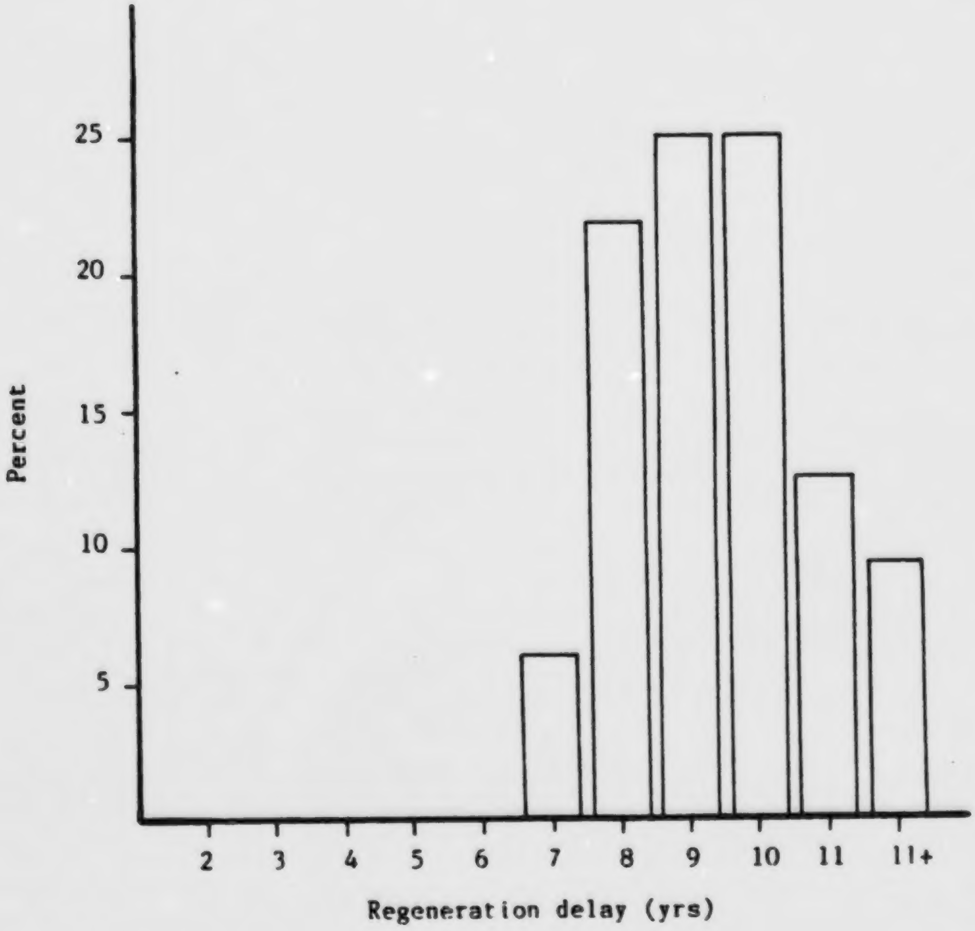
Crossley (1976) describes natural regeneration of lodgepole pine stands after clearcutting and scarification in west central Alberta. Crossley examined 32 cut blocks which were judged insufficiently stocked in a regeneration survey made six years after harvesting. Over time, an increasing number of the cut blocks became sufficiently restocked. Table 4 shows the progression.

Table 4. Progression of Lodgepole Pine clearcuts to minimum stocking standards (After Crossley, 1976)

Years Since Harvest	Percent Success	Cumulative Percent Success
4	0	0
5	0	0
6	0	0
7	6.2	6.2
8	21.9	28.1
9	25.0	53.1
10	25.0	78.1
11	12.5	90.6

The regeneration delays for these cut blocks vary from seven to 11 years, or greater. The percent distribution of the regeneration delays is given in the percent success column of Table 4. Figure 1 below presents the distribution of regeneration delays as a histogram.

FIGURE 1: DISTRIBUTION OF REGENERATION DELAYS IN CLEARCUT LODGEPOLE PINE, ALBERTA



Crossley (1976) also examined the ingress of tree regeneration over time with four cut blocks harvested 13-15 years before his study. He found that:

(1) Ingress of surviving regeneration following harvest lasted for a period of nine to 15 years (average 12 years). Following scarification it lasted for eight to 12 years (average 10 years).

(2) Ingress generally peaked in the third year following scarification, provided that scarification was not delayed beyond the first year following harvest.

(3) The longer that scarification was delayed following harvest, the more erratic the ingress of the surviving regeneration.

(4) The ranges in height growth of pine of similar age within a plot of apparently uniform site perhaps can be attributed to genetic variation.

(5) The ingress of poplar exhibited the same duration as the pine.

In this study immediate scarification resulted in an average of 12,741 living trees per acre at the conclusion of ingress, and delayed scarification resulted in an average of 5,054. The latter suggests that the first seed released from the serotinous pine cones fell on unreceptive ground, and delayed scarification therefore resulted in a decrease in the effective seed supply.

Crossley found that lodgepole pine regeneration stocking following scarification and the prolonged release of seed provided much more acceptable stand densities than those originating from wild fire. After fire most of the seed from the serotinous cones was immediately released and extreme overstocking usually resulted.

The large number of factors affecting natural regeneration occur in nature in a huge number of combinations. This produces a wide spectrum of results from dense, overstocked, natural stands to ireregularly stocked, brushed-in areas. The backlog areas represent those combinations of factors producing the poorest results.

GROWTH OF NATURALLY REGENERATED STANDS

For a given species and genetic stock quality every forest site has a fixed innate productive capacity because a given area of land provides just so much soil moisture, soil nutrients, carbon dioxide and sunlight for plant growth. The degree to which this fixed potential yield is realized by actual forest stands depends on:

- the regeneration delay
- the degree of stocking

REGENERATION DELAYS

The time taken after logging to produce a productive stand affects the average yield produced over time and delays the next harvest by a time equal to the regeneration delay. Figure 2 illustrates this point.

In Figure 2 yield A is obtained at age t when there is no regeneration delay. If there is a regeneration delay then at time t the yield drops to B because the yield curve is shifted along the time axis to the right.

THE DEGREE OF STOCKING

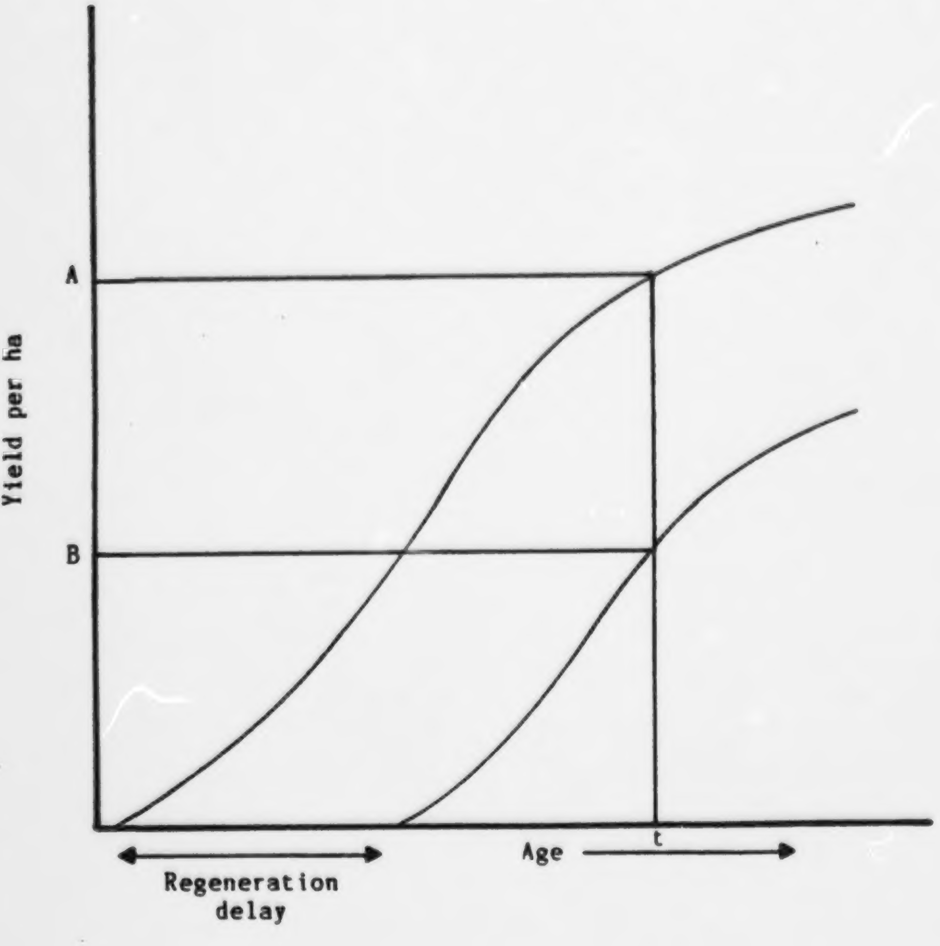
Even though the principle of a fixed potential yield is true for a wide range of initial densities on a given site:

- some densities are too low to capture the productive potential;

- a wide range of initial densities can achieve the productive potential but low initial densities take longer to do this than high initial densities.

For example, Pienaar and Turnbull (1973) analyzed the total stand basal area growth of slash pine (Pinus elliottii) in South Africa. They found that initial densities of 2,964 stems per hectare

FIGURE 2: THE EFFECT OF REGENERATION DELAY ON YIELD



down to 494 could ultimately sustain an equal maximum amount of basal area. Initial densities below 494 stems per hectare were not able to reach the potential basal area yield. Above this lower limit all stands converged towards an identical amount of basal area per hectare, determined by the productive capacity of the site. The rate of convergence towards the same potential yield was dependent on initial density.

Figure 3 shows how initial density affects the yield from a forest stand. In Figure 3 the initial densities 1 and 2 are too low to ever achieve the potential yield. Initial densities 3, 4 and 5 will all reach the potential yield. The lower densities 3 and 4 are approaching this point more slowly than the higher density 5. At all ages before the convergence to the potential yield, the yield of the lower initial densities will be lower than the higher density. This convergence is often called "the trend toward normality."

For natural stands differing degrees of site occupancy may also occur from irregular spacing or clumping, and brush competition. Plantations, with a regular stocking will provide a better site occupancy than irregularly spaced natural stands suffering from brush competition, containing an undesirable deciduous component.

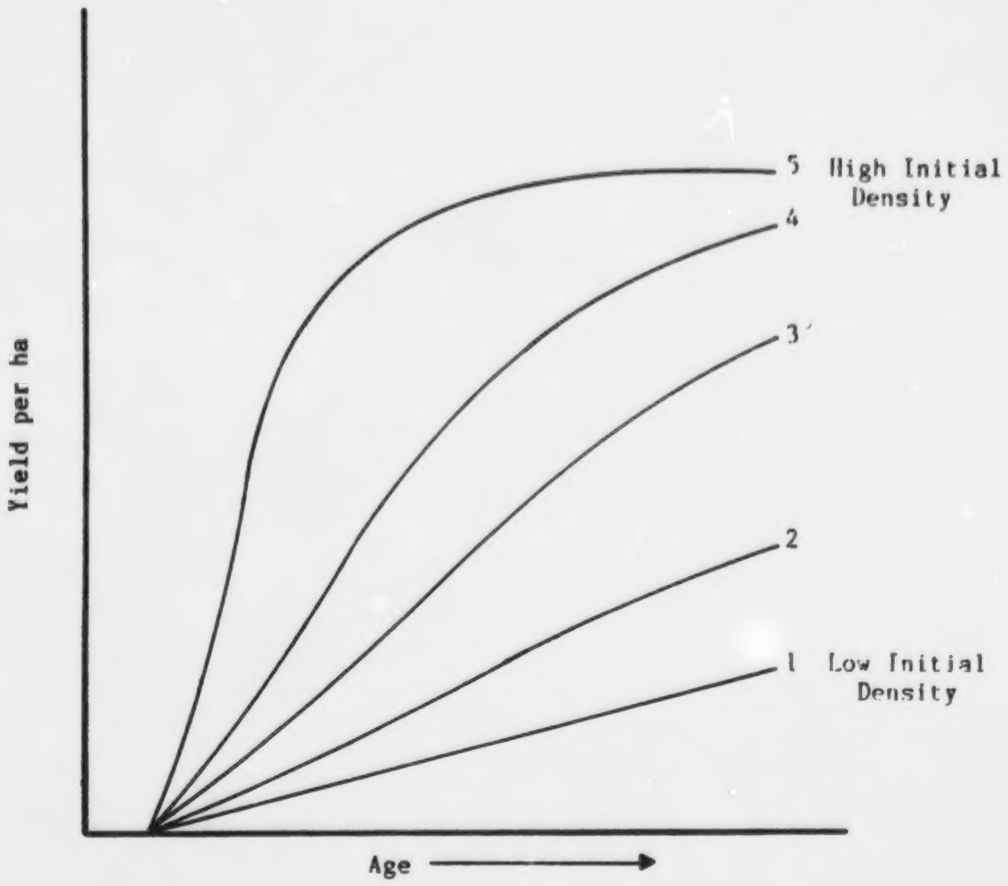
EXAMPLES

After logging, the natural stands which are established show a wide range of initial densities. For example, Wall (1983) studied early stand development after clearcutting on the Cape Breton highlands. Sampling and data collection was taken from 1978 to 1982. Stumps examined in seven cutover blocks indicated former tree densities at harvest of 1,041 +/- 581 stems/ha. The 18 selected clearcuts had been harvested two to 15 years previous to the study, with 50% in the three to four year age category. All of the stands had been predominantly balsam fir (Abies balsamea (L.) Mill), originating around 1915. Stands harvested since the mid 1970's had been severely defoliated by the spruce budworm before harvest and this probably affected their regeneration.

The conifer regeneration on the clearcuts was variable. Sixteen clearcuts were over 40% stocked but only three were over 80% stocked. Stocking was a visual estimate of cover, to the nearest 10%. Coniferous regeneration densities ranged from 800 to 27,500 stems per hectare.

After an initial lag period of two to four years, height growth of balsam fir rapidly increased until about 10 years after cutting

FIGURE 3: THE RELATIONSHIP OF INITIAL DENSITY AND YIELD



when cover by non-commercial species was greatest. No general growth suppression by other vegetation could be found. McDonald (1983) examined a series of clearcutting experiments in north-central California representing 20 years of research on forest regeneration after clearcutting. Adequacy of natural regeneration was evaluated periodically for 19 years. The evaluation was subjective and took into account numbers of conifer seedlings by species, distribution and general assessment of vigour. Number and distribution of hardwood trees and woody shrubs also were assessed. Twenty-four clearcut units ranging from 0.8 to 24 hectares were surveyed annually for the first two to four years after cutting and periodically thereafter to age 15.

Regeneration categories and rating criteria were:

(1) Adequate or better - seedlings no farther apart than 3.7 m and regularly distributed;

(2) Marginal - spacing of seedlings near 3.7 m but distribution clumpy;

(3) Failure - large areas devoid of seedlings.

Of the 24 clearcut units 15 years after cutting, the conifer regeneration was adequate on seven, marginal on 13 and a failure on four.

Amount and distribution of natural regeneration followed the same general pattern found for seedfall. Regeneration was most abundant near the forest edge and least abundant near the centre. It also was best in the northeast quadrant extending in a pie-shaped wedge to near the clearcut centre. In addition to the northeast quadrant, a shallow wedge of increased regeneration also was observed in the southwest quadrant in many clearcuttings. Westerly portions of most clearcuts tended to have fewer conifer seedlings than other portions.

The sites in McDonald's study were highly productive and re-invasion of the disturbed ground by all types of vegetation was rapid and complete. Mortality of ponderosa pine and California white fir was high in the first growing season and decreased rapidly thereafter. After two to three years early seedling losses from the principal causes, drought, damping-off fungi, cutworms and birds, were mostly over.

Browsing by deer affected height growth of some ponderosa pine seedlings, but was of minor consequence overall. After site preparation by broadcast burning or windrow and burning, large amounts of nutrients were released. This flush of nutrients affected the woody and herbaceous vegetation for the first year and also the second to a lesser extent. The chief effect was that the tender shoots and new leaves of nearly all plants became palatable including manzanita (Arctostaphylos viscida), tan-oak (Lithocarpus densiflorus), poison-oak and others that were usually untouched. In a new clearcut, the deer had a wide range of nutritious succulent browse so that conifer seedlings were not subject to heavy damage.

Height growth of ponderosa pine seedlings depended mostly on the degree of competition from woody shrubs or other conifer seedlings. Fourteen-year-old pine seedlings growing in dense manzanita, for example, ranged in height from 1.2 to 4.3 m with less leader growth each year as their general health and vigour declined. Stocking of whiteleaf manzanita and deerbrush was high initially and continued high throughout the study.

Antos and Shearer (1980) described vegetation development on disturbed grand fir sites in northwestern Montana, in the Swan Valley. This valley lies east of Flathead Lake and occupies the trench between two mountain ranges. Fourteen clearcuts in the Swan Valley were sampled. Years since cutting ranged from seven to 16. Site preparation was mainly by bulldozer piling and burning of slash.

Most of the clearcuts were adequately stocked with young trees, but the density and species composition varied greatly. Larch (Larix occidentalis) was the most common species regenerated. On about half of the clearcuts, larch regeneration dominated the new stands. When a larch seed source was deficient, the developing stands varied greatly in composition and took much longer to become stocked with Douglas-fir, white pine, spruce (a hybrid complex of Picea glauca and P. engelmanni) and grand fir.

On the drier exposures, stand establishment was slower and more difficult. Tree height growth was slower and stem distribution was poor. The young trees tended to be clumped on areas with the most disturbed soil and the least competition from undergrowth vegetation.

Weetman, Grapes and Frisque (1973) reported on reproduction and ground conditions five years after pulpwood harvesting on 37 study areas in eastern Canada. The natural reproduction was variable. Assuming that 800-1,000 well-spaced dominant trees were needed per acre, then reproduction five years after logging, on most of the study areas was far from ideal. Jack pine (Pinus banksiana) regeneration tended to be sparse; balsam fir was uneven, patchy and overly dense in places; black spruce was very variable and often overtopped by brush and sedge; red spruce (Picea rubens) and white spruce in mixed wood stands were very sparse and suppressed by hardwood brush.

In most of these areas the only scarification provided was that due to the logging operation. Except in one instance, this was insufficient to provide suitable seed beds for coniferous species.

THE REGENERATION DELAY PROBLEM

THE PROBLEM

All denuded land will eventually restock naturally; even backlog areas. In previous sections of this report it has been shown how variable natural regeneration is; from micro-site to micro-site on the same opening and between openings. For backlog areas the question is:

- given that regeneration has not yet occurred, and the area has been designated backlog, how much longer would it take to regenerate naturally if left untreated?

There are three ways of answering this question. They are described below.

A SUBJECTIVE ESTIMATE

One way of approaching the problem is to make a series of educated guesses about the regeneration delays for backlog forest areas.

A DETERMINISTIC MODEL

The work of Lavender et al (1956) described earlier, produced a model which predicted regeneration delay for Douglas-fir given known values of various site variables. In principle, this idea could be extended to all the species in B.C. Then, given known site conditions, the regeneration delay for backlog areas could be predicted.

A DISTRIBUTION OF REGENERATION DELAYS

The variability observed in natural regeneration delays means that for every thousand hectares logged a percentage of the area will regenerate quickly, another percentage after several years and another percentage after many years. Crossley (1976) expressed this idea as a table showing the percent of clearcuts regenerated successfully as a function of time. This was described previously in the report and Crossley's results were presented as Table 4 and Figure 1.

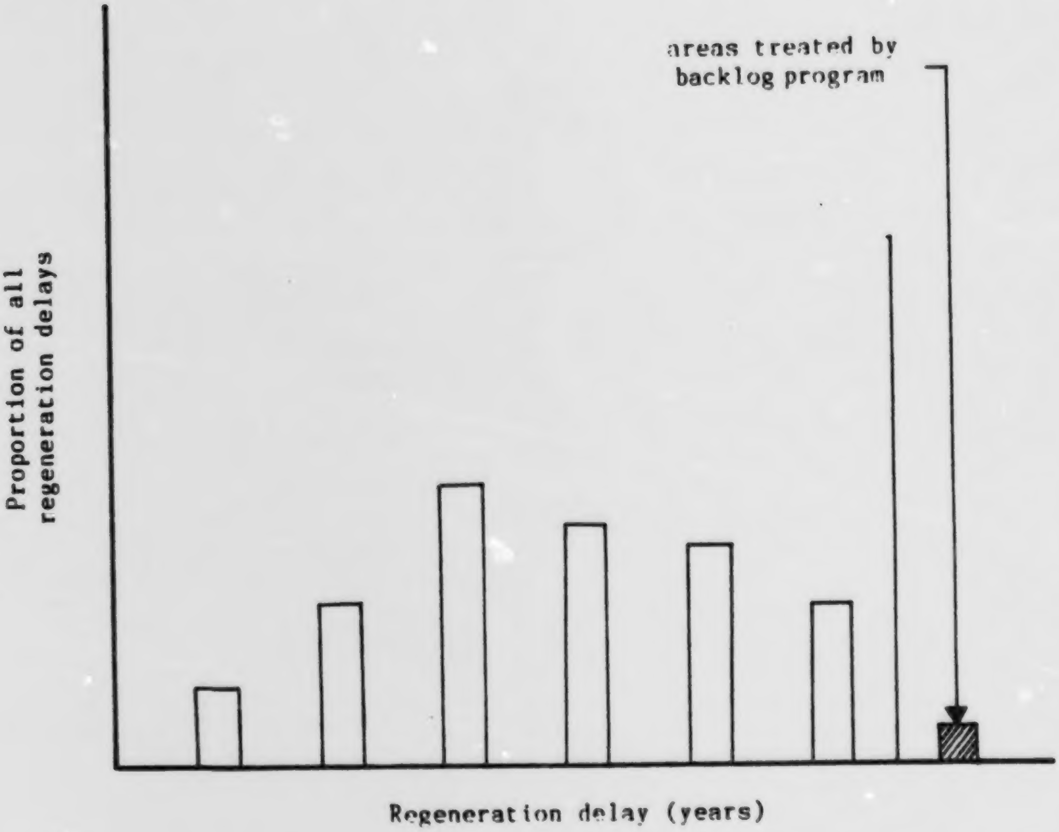
Building on Crossley's 1976 paper, backlog areas can be thought of as the right hand tail of the complete distribution of natural regeneration delay. Figure 4 illustrates this point. Those regenerated areas where the delay was judged acceptable would be to the left of the vertical line in Figure 4. Those areas to the right of the line are backlog areas. The backlog restocking program is directed at those areas to the right of the line in Figure 4. Once treated, the expected long regeneration delay has been prevented. The years of growth saved by the program are equal to the expected regeneration delay without treatment minus the years since logging.

This idea could be applied to backlog areas if the distribution of regeneration delays could be constructed from actual data, the cut-off point for backlog areas identified, and the time since logging for the FRDA backlog areas was known. Then, the distribution could be used to estimate the expected regeneration delay for the backlog areas if left untreated.

SELECTION OF A METHOD

For this study the third alternative, a distribution of regeneration delays was selected. Educated guesses were rejected because their supporting rationale is often unclear and estimates vary among experienced professionals. Building a set of predictive models like the one of Lavender et al (1956) would require a massive data collection and analytical exercise taking many years. Regeneration delay distributions can be estimated from the existing data base in the MOFL History Record System. Regeneration delays for treated backlog areas can also be obtained from the same source. Finally, enough information exists in the history record to identify broad biological strata having the same distribution pattern of regeneration delays.

FIGURE 4: THE POSITION OF BACKLOG AREAS IN THE REGENERATION DELAY DISTRIBUTION



THE LEVEL OF STOCKING PROBLEM

THE PROBLEM

A previous section of the report discussed the effect of different initial levels of stocking on the yield of forest stands. For backlog areas the questions are:

- how should the low level of stocking of untreated backlog stands be estimated?

- how should the effect on wood yield of low initial stocking from untreated backlog stands be described?

There are three alternatives available for answering these questions. They are described in the following sections.

MEAN ANNUAL INCREMENT

For a given forest type the estimated average regeneration delay expected for all backlog stands can be used to reduce the expected mean annual increment obtained from promptly regenerated stands. For example, suppose a stand with a five-year regeneration delay produces an MAI of 5 m^3 per year at a rotation of 90 years (five years for the delay 85 years for growth). The harvest yield would be 450 m^3 per hectare. If the average regeneration delay for backlog stands were 30 years then the MAI for these stands could be calculated as 450/115 or 3.9 m^3 per hectare per year. The new rotation would be 130 years (30 years for the delay, 85 years for growth).

To incorporate the idea of a low level of stocking for backlog stands the assumption of no convergence to normality would have to be made. Then, if the stocking level of backlog stands averaged 50% of the usual well-stocked stand the MAI would be further reduced by 50%. In the example given above, the MAI of 3.9 m^3 would be further reduced to 1.95 m^3.

COMPUTER SIMULATION MODELS

Since the mid 1960's computer models have been built which attempt to simulate growth, yield, stand structure development and mortality in a single forest stand. Several types of model have emerged and have been categorized by Munro (1974) and Mitchell and Cameron (1985).

Whole stand models recognize the stand as the basic unit that responds to environmental factors and silvicultural practices. Species, age, site quality and density or management regime are related directly to volume, basal area, diameter, height, number of trees and other stand parameters. These models are ideal for short-term growth projections of conventional inventory plots in support of management plans. Yield tables can be generated by these models.

Individual tree models differ in that they retain information about every tree in a simulated stand. This may include the spatial position or co-ordinates of each stem, and its vigour, competitive stress and upper stem diameters. The tree is the basic biological unit of growth rather than the stand, which is now an aggregation of competing stems. These individual tree models do not attempt to forecast the development of particular trees measured in the field. Instead, they simulate the growth of trees as a means of incorporating the dynamics of stand development into yield projections.

Crown models employ the crown as the centre of activity for growth and competition for growing spaces. These models are extensions of individual tree models and always incorporate inter-tree distances. Crown models are costly to develop and operate because of their detail and dependence on foresters with highly specialized training.

Several stand simulation models are available and each one can be used to simulate stands of low stocking levels, and produce a set of yield tables. Regeneration delays can be entered at the time of a run, or by adding the regeneration delay to the ages shown in the yield table.

YIELD FUNCTIONS

Yield functions present growth and yield information in the form of equations. Examples are stand volume, stand basal area and stand average diameter as separate functions of age. In British Columbia three kinds of yield function are available from the B.C. Ministry of Forests and Lands (MOFL). These are:

- Chapman-Richards yield functions
- variable density yield functions
- Ek-Payandeh yield functions

All three function types are available for all growth types in B.C. The Chapman-Richards and Ek-Payandeh yield functions represent average stocking levels. As their name implies, the variable density yield functions will provide yield projections for a variety of stocking levels.

Chapman-Richards Yield Functions

The Chapman-Richards generalized growth model is:

$$\text{Volume} = b_1(1-e^{-b_2 \text{Age}})^{b_3} \qquad (1)$$

The coefficients b_1 to b_3 were derived by the MOFL from Marquardt's non-linear regression algorithm for each combination of growth type, site class and diameter utilization limit. That is, the data set was first stratified by growth type, site class and merchantable diameter limit. Then the Chapman-Richards function was fitted to each stratum.

Variable Density Yield Functions

Because the Chapman-Richards curves represent average stocking there is considerable variation between the individual sample values and the curve (B.C. Ministry of Forests (1983)). This variation can be reduced by including additional variables, which break the asymptotic value, b_1, of the Chapman-Richards model into components describing the growing conditions (site index) and the stand structure (basal area and diameter). The MOFL has produced variable density volume functions of the form:

$$\text{Volume} = b_1 {*} SI {*} BA {*} D {*} (1-e^{b_2 A})^{b_3} {*} e^{b_4 SI + b_5 BA + b_6 D} \qquad (2)$$

where: b_1 to b_6 = non-linear regression parameters
A = stand age
BA = stand basal area (m^2/ha)
D = stand mean diameter (cm)
SI = site index

In these functions stand basal area is used to represent different levels of stocking, as follows. First, basal area functions are used to predict the basal area in a stand of average stocking level as a function of age. Then for a different stocking level the relative basal area (RBA) is calculated from:

$$RBA = \frac{\text{Known basal area for the different stocking level}}{\text{Calculated basal area for average stocking}} \qquad (3)$$

Then future stand basal area for the different level of stocking is calculated from:

$$BA = RBA\ b_1\ SI(1-e^{b_2 A})^{b_3} {*} e^{b_4 SI} \qquad (4)$$

where b_1 to b_4 = non linear regression parameters.

By substituting this basal area for the different level of stocking into equation (2), a volume prediction can be obtained.

For the variable density yield tables the data set was stratified by growth type but not by site class. One set only of the parameters b_1 to b_6 was estimated from the complete data set because site index was an independent variable.

Ek-Payandeh Yield Functions

As with the variable density yield function, the Ek-Payandeh function was fitted to the complete data set for each growth type (B.C. Ministry of Forests and Lands (1987)). The data were not stratified by site class because site index was an independent variable. The Ek-Payandeh function has the form:

$$\text{Volume} = b_1 * SI^{b_2} * (1 - e^{b_3 * Age})^{b_4 * SI^{b_5}} \qquad (5)$$

where b_1 to b_5 = non linear regression parameters.

The MOFL estimates the parameters for the Ek-Payandeh function only at one merchantable diameter limit, 7.5 cm+. Volumes for other levels of utilization are obtained by multiplying the volume for 7.5 cm+ by a 'volume ratio.' The volume ratio is itself a function of the form:

$$VR = 1.0 + \frac{b_1 + b_2 * SI}{Age - \left[b_3 + \frac{b_4}{SI - b_5} \right]} \qquad (6)$$

where: VR = volume ratio
b_1 to b_5 = non linear regression parameters having different values to those in equation (5).

The relationship between volume ratio and age is hyperbolic with an upper symptote of 1.0.

Discussion of Yield Functions

To predict the yield from backlog NSR stands the prediction method must incorporate:

- regeneration delays
- understocked stands
- convergence of yield towards normality.

In the three types of yield function available, regeneration delays are easily accomodated. For the Chapman-Richards function, the parameter b_2 in equation (1) is made equal to b_2 minus regeneration delay. For the variable density yield function, the parameter b_2 in equation (2) is made equal to b_2 minus regeneration delay. For the Ek-Payandeh function, the parameter b_3 in equation (5) is made equal to b_2 minus regeneration delay. In all three cases this will shift the yield curve along the time axis as shown in Figure 2.

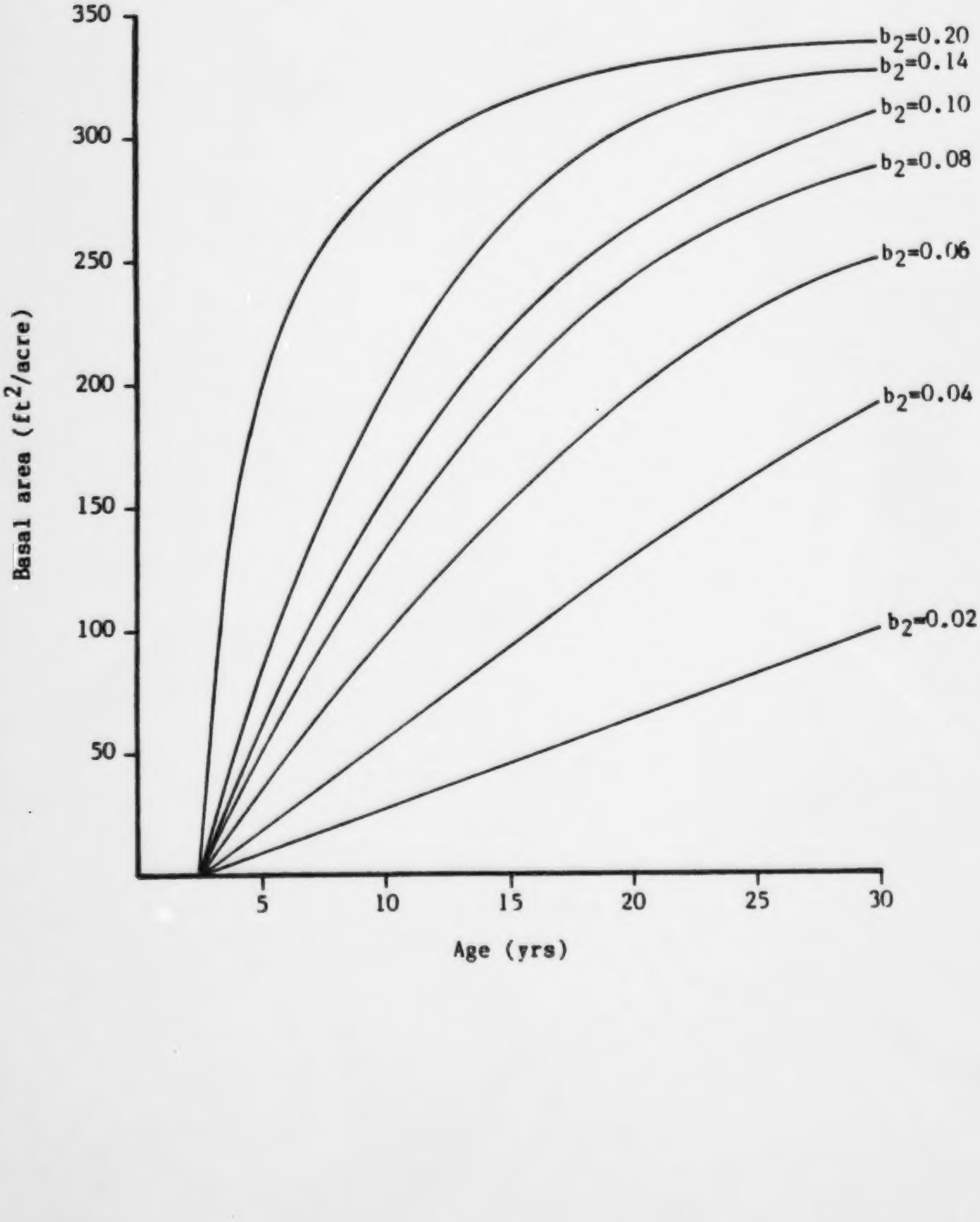
All three yield functions can be used to represent understocked stands. For the variable density yield function relative basal area (RBA) is used as described previously in the description of that function. For the Chapman-Richards and Ek-Payandeh functions the value of one parameter can be re-calculated to fit an actual stocking level different from the average stocking represented by the MOFL parameter values. This parameter modification is described below.

In the Chapman-Richards model, equation (1), parameter b_1 represents the maximum yield possible, b_2 affects the rate at which the maximum yield is approached, and b_3 determines the position of the inflexion point relative to the maximum yield. Pienaar and Turnbull (1973) showed that the parameters b_1 and b_3 are independent of the initial level of stocking, but parameter b_2 is not. For each initial level of stocking a different b_2 value is appropriate which then stays fixed for the life of the stand unless the level of stocking is changed again, by thinning for example. Varying b_2 only, for constant values of b_1 and b_3 will produce a series of growth curves. The lower the initial stocking, the smaller the value of b_2. Pienaar and Turnbull (1973) constructed a set of stand basal area yield curves for slash pine (*Pinus elliottii*) plantations in South Africa. The value of b_1 was 337.5 ft^2/acre, b_3 was 1.441 and b_2 varied from 0.02 to 0.20. Figure 5 shows the resulting set of yield curves.

In Figure 5 all the curves are converging to the same final yield so that convergence to normality is also achieved by the set of curves in Figure 5.

For backlog NSR stands, if the level of stocking, for example the stand basal area at a given age, is know, then the correct value of b_2 for this level of stocking can be calculated by re-arranging

FIGURE 5: BASAL AREA YIELD CURVES FOR DIFFERENT STOCKING LEVELS (CHAPMAN-RICHARDS FUNCTION) AFTER PIENAAR AND TURNBULL 1973



equation (1) so that b_2 is the only unknown. This changes equation (1) into equation (7) below.

$$b_2 = -\ln \frac{\left[1 - \left(\frac{BA}{b_1}\right)^{\frac{1}{b_3}}\right]}{Age} \qquad (7)$$

where: b_1 to b_3 = parameters of the Chapman-Richards function
BA = basal area for a specific age.

These values of b_1 to b_3 together with the regeneration delay t_0 will predict the basal area yield for a backlog NSR stand.

In this report the concern is for predicting volume yields. The same technique described above would allow a particular b_2 value to be estimated for predicting volume yields for backlog NSR stands.

The Ek-Payandeh yield function is a modification of the Chapman-Richards equation. The maximum yield parameter b_1 in equation (1) is modified in the Ek-Payandeh function so that:

$$b_1 \text{ (Chapman-Richards)} = b_1 SI^{b_2} \qquad (8)$$

The parameter b_3 in equation (1) is modified in the Ek-Payandeh function so that:

$$b_3 \text{(Chapman-Richards)} = b_4 SI^{b_5} \qquad (9)$$

For the Chapman-Richards function a different parameter set is required for each site class. For the Ek-Payandeh function one set of parameters is sufficient because site index is added as an independent variable. In the Ek-Payandeh function the parameter b_3 is dependent on level of stocking. Keeping all other parameters constant and changing b_3 will generate a series of yield curves which represent different stocking levels.

For backlog NSR stands, if the level of stocking is expressed as a volume at a given age then the correct value of b_3 can be calculated by re-arranging equation (5) so that the parameter b_3 is the only unknown.

For the Ek-Payandeh function this changes equation (5) into equation (10) below.

$$b_3 = -\ln \frac{\left[1 - \left(\frac{VOL}{b_1 SI^{b_2}}\right)^{\frac{1}{b_4 SI^{b_5}}}\right]}{Age} \qquad (10)$$

where: b_1 to b_5 = parameters of the Ek-Payandeh function
VOL = volume per hectare for a specific age

The value of b_3 obtained for the level of stocking representing backlog NSR stands would provide a yield curve for these stands. Regeneration delay is included by replacing age with (Age minus regeneration delay). This shifts the curve along the X axis to the right. For example, delay the volume at 50 years after logging and a 20-year regeneration delay is equal to the volume produced at 30 years after logging when there is no regeneration delay.

SELECTION OF A METHOD

For this study the Ek-Payandeh yield function was chosen to describe the yield of untreated backlog areas.

Using mean annual increment does not give an idea of the changing yields over time from untreated backlog areas. Neither can the convergence toward normality cannot be described by the mean annual increment method.

There are several problems with the use of computer simulation models. First, most models have been calibrated for one or two species only and in a limited geographical range. Second, different simulation models show different results even when calibrated for the same species. The differences are not confined to simple proportional differences in yield or stand diameter but include major differences in growth and mortality patterns. These differences are caused by different model structures and assumptions about growth responses. When compared to real stands or judged against accepted growth and yield principles, all simulation models perform well for a restricted set of conditions. None seem to perform well over the complete range of conditions. For example, some are good for unmanaged, well-stocked stands but not for treated and low density stands.

For this study several different models would have to be used to try and cover the whole province. Even then the complete range of growth types could not be simulated. The results would therefore be incomplete and inconsistent.

The MOFL has replaced the Chapman-Richards functions with the Ek-Payandeh functions. The variable density yield equations cannot describe the convergence toward normality of stands of different initial stocking.

The Ek-Payandeh yield function is available for all growth types in B.C. It is used by the MOFL in its wood supply analyses. The regeneration delay for untreated backlog areas can be included directly in the formula. The function can be modified in a defensible way to include both low initial stocking levels and the convergence toward normal yields.

The Level of Stocking in Backlog Stands

To use equation (6) to calculate the correct value of parameter b_3 for untreated backlog stands a representative volume at a given age must be determined. The data present in the silviculture history records were not suitable for this task. The stocking levels, or volume at a particular age for untreated backlog stands was determined as follows.

In the course of developing their variable density yield projections, the MOFL determined the minimum stocking level, the mean stocking level and the standard deviation for all the natural stands in the provincial inventory data base. The stocking levels are expressed as relative basal area (RBA). The consultant believes it is reasonable to assume that untreated backlog stands fall into the minimum 10% of stocking levels. Assuming a normal distribution of RBA about the average stocking level, then the average stocking for untreated backlog stands would correspond to the bottom 5% RBA value. This value is easily calculated from:

$$\text{RBA for untreated backlog stands} = \text{Mean RBA} - 1.645 * \text{SD} \qquad (11)$$

where: SD = standard deviation of RBA
1.645 = the Z distribution value

The Z value of 1.645 is the number of standard deviations of the normal distribution which leaves 5% of the area under the normal curve in each tail of the distribution.

When producing the yield curves for untreated backlog areas the consultant calculated the appropriate values for RBA from equation (11) and Inventory Report #3. Then it was assumed that relative basal area and relative volume were similar. Volumes from the Ek-Payandeh curves for the usual average stocking level at age 30 after stand establishment were reduced by the appropriate RBA factor. The result was a volume representative of the untreated backlog stands 30 years after their eventual establishment, (i.e. excluding the regeneration delay). These volumes were substituted in equation (6) to obtain the correct b_3 value for untreated backlog stands.

ESTIMATING BACKLOG REGENERATION DELAYS

Actual regeneration delays were estimated from information available in the MOFL History Record System. Then they were expressed as a distribution showing the proportion of the regenerated area having a regeneration delay of one to three years, three to six years, etc. This is a computer data base whose smallest unit of information is a logged opening. A full description of the history record system is given in the MOFL Silviculture Manual (MOFL, 1986).

The objective of the History Record System is to record the status of denuded or tended B.C. forest land. The complete database contains approximately 67,000 records which occupy about one kilobyte of memory. Each individual history record is broken into nine sections labelled A to I. This project used data from sections A and B. Section A gives a description of the complete History Record area. Section B shows the stocking status of all the land covered by the history record. It shows the first year of denudation and subsequent history of change in regeneration status. There are two parts to this stocking status table. The first, or year of action part, indicates when any area was added to the record. It also shows any subsequent arithmetic adjustments, the total area and the method of measurement. For example, for a given opening the logging may have taken more than one year, so the area added each year will be recorded. The second part of the stocking status table is the classification part. This part shows how the total area, from the year of action part, is distributed between non-productive and productive land. The productive land is split between satisfactorily restocked and not satisfactorily restocked.

Successive regeneration surveys show how much of the opening in the original year of action has regenerated naturally. For example, if 320 hectares were logged in 1978 and a survey in 1981 showed that 100 hectares were satisfactorily stocked, then 100 hectares would have a three year regeneration delay. If a second survey in 1983 showed a further 200 hectares regenerated then this area would have a five-year regeneration delay. Since surveys are not done annually, regeneration delays calculated in this way are approximate and probably overestimate the actual regeneration delay.

From the History Record System a subset of data records was obtained. Only records containing natural regeneration were selected and from these a 15% sample, representative of all parts of the province, was taken. This produced a data file containing approximately three and one half million bytes of information. More than 3,000 regeneration delays were calculated from these data using the method described above.

MANIPULATING THE HISTORY RECORD DATA

To manipulate the history record data a set of four computer programs was written.

The first program strips the raw data file of unneeded information and calculates regeneration delays and areas regenerated. The resulting data file is automatically sorted by aspect, slope, elevation, site, forest type and biogeoclimatic zone. These six sorted files are then written to the hard disk.

The second program uses any of the files produced by the first program. It selects records from these files according to conditions given for:

- History Record key number
- aspect
- slope
- elevation class
- site
- inventory type
- biogeoclimatic zone
- regeneration delay
- size of area regenerated

The third program can use the output files produced by either of the first two programs. This program selects any number of columns from these files and writes the selected columns to a new file.

The fourth program calculates the proportion of the total regenerated area in the data base which falls into each regeneration delay. This program uses the files produced by either of the first two programs. The size of the regeneration delay class in years is supplied by the user; for example one year or three year classes.

CONTINUOUS PROBABILITY DISTRIBUTIONS

The distribution of regeneration delays was described by using a continuous probability function. Regeneration delays are usually expressed as a number of complete years. The regeneration delay for a given logged area will not always be a number of complete years. The time taken to regenerate will often include a partial year, and could be considered as a continuous variable. The probability distribution for a continuous variable is called a continuous probability distribution. Continuous distributions are frequently very easy to deal with, and for this reason, a discrete random variable is often treated as if it were continuous.

Regeneration delay could be treated as either a continuous or a discrete variable. Because it was more convenient to treat as a continuous variable, the consultant expressed the distribution of regeneration delays over time as a continuous probability distribution.

With a continuous distribution, where the number of possible values of the random variable is infinite, the probability of the occurrence of some specific value is not spoken of. Rather the probability that the random variable (x) lies between two specified points is spoken of. An example is the probability that (x) lies between 1.0 and 2.0. The formula for the curve describing a continuous probability distribution is called a probability density function (pdf).

All probability density functions must meet two conditions:

(1) Non-negativity

$$f(x) \geq 0 \text{ for all } x \qquad (12)$$

(2) Area under curve must total to 1

$$\int_{-\infty}^{+\infty} f(x)dx = 1 \qquad (13)$$

The probability that x lies in any specified range, say between x = 1 and x = 2 is equal to the area under the pdf between these two x values. This area is obtained by integration of the pdf between the two x values.

Several pdf's are in use to describe real world phenomena. Examples are, the Weibull, normal, beta and gamma distributions. The gamma distribution has the characteristics that its minimum value is zero, while the maximum can extend as far as required. Many real world phenomena, including regeneration delays, have a floor at zero but a relatively high ceiling. These distributions have a mean value which is larger than the mode or most frequent value. The gamma distribution is very flexible and can create many shapes. For these reasons the consultant chose the gamma distribution to represent the distribution of regeneration delays.

The Gamma Distribution

The gamma distribution has two parameters, a and b, and its pdf is

$$f(x) = \frac{b^{a+1}}{\Gamma(a+1)} x^a e^{-bx} \text{ for } x > 0 \qquad (14)$$

$$= 0 \qquad \text{elsewhere}$$

The capital Greek letter gamma, which appears in the denominator designates the gamma function, a mathematical relationship which has the value:

$$\Gamma(n) = (n-1)! \qquad (15)$$

Therefore the gamma probability distribution function (the pdf) may be written:

$$Y = f(x) = \frac{b^{a+1}}{a!} x^a e^{-bx} \quad \text{for } x > 0 \qquad (16)$$

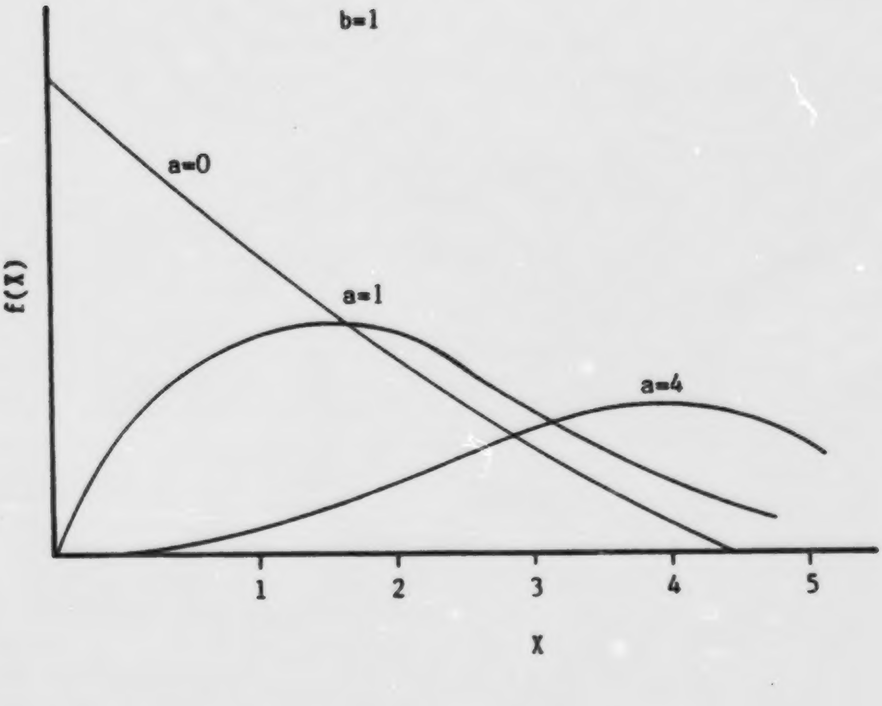
$$= 0 \qquad \text{elsewhere}$$

Equation (16) is the probability density function.

The general shapes of the graphs of the density functions (pdf's) for the gamma distribution where b equals one and a varies, are shown in Figure 6.

It can easily be demonstrated that the area under the curve is equal to one for all values of a. In the pdf for the gamma distribution, the parameter b changes the relative scale of the two

FIGURE 6: THE GAMMA DISTRIBUTION



axes, and the parameter a determines the location of the peak of the curve.

The peak of the curve, the mode, is at $x = a/b$.

The mean of the gamma distribution is given by $a+1/b$. The variance is equal to $a+1/b^2$.

Estimating the Parameters of the Gamma Distribution

Two methods of estimating the parameters a and b of the gamma distribution from the History Record Data were examined:

- using multiple linear regression
- using an iterative method.

To use multiple regression the pdf in equation (16) can be transformed to:

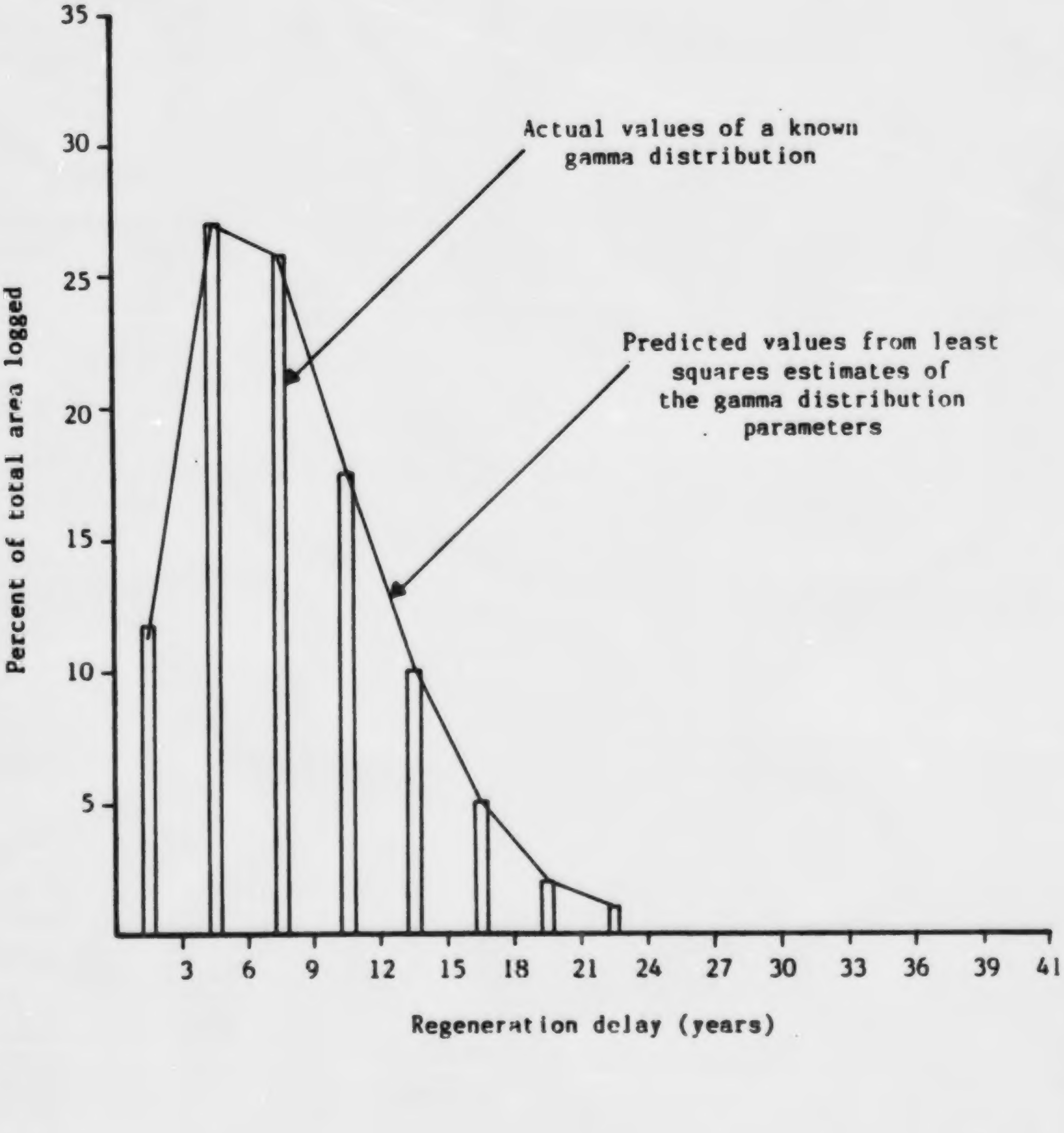
$$Y = b_o + b_1 X_1 + b_2 X_2 \tag{17}$$

where: $Y = \ln Y$ (natural logarithm of Y)
$b_o = \ln \left[\frac{b^{a+1}}{a!} \right]$,
$X_1 = \ln X$
$X_2 = X$
$b_1 = a$
$b_2 = -b$

In this report, for regeneration delays the variable Y is the proportion of the denuded area regenerated. The variable X is the corresponding regeneration delay.

As a preliminary test of this method a set of Y values were generated from the gamma distribution equation, setting $a=3.0$ and $b=1.25$. The multiple regression technique estimated the value of a to be 3.065 and b was estimated to be 1.265. This preliminary test appeared to be promising and is illustrated in Figure 7. When real

FIGURE 7: REGRESSION ESTIMATES OF A GAMMA DISTRIBUTION FROM DATA GENERATED BY KNOWN VALUES OF a AND b



data from the history records were used the distributions were not smooth. An example is given in Figure 8.

The irregularity of the data produced least squares estimates of the parameters a and b which did not produce a good fit to the real data. The parameter value a was usually estimated as zero because the least squares procedure fitted a declining exponential type of curve through the data. The net result was least squares estimates of the parameters a and b that were not consistently able to fit the original distribution of regeneration. In Figure 8 the least squares process has fitted an exponential type curve which declines to the right. The peak of the curve is not produced because the parameter a has been estimated as zero.

Because of these problems a second method of parameter estimation was developed which included three steps.

(1) An iterative process of estimating the parameter values, plotting the resulting distribution to make a visual check, re-estimating the parameters to improve the visual fit.

(2) Once a parameter pair which seemed best had been chosen a goodness of fit test was done using a paired t-test, on the predicted and observed distribution values. The null hypothesis was that the mean difference between predicted and observed values was zero.

(3) Steps (1) and (2) were repeated with the objective of minimizing the calculated t-value and therefore maximizing the goodness of fit.

To facilitate this process a fifth computer program was written to plot the observed area proportions against the regeneration delay and then to plot a number of calculated gamma distributions against the original data. In this way, values for a and b could be easily changed and the resulting gamma distributions plotted against the original data.

An example result is given in Figure 9. Here a curve with a peak has been produced.

A BIOLOGICAL GROUPING OF REGENERATION DELAYS

The regeneration delays obtained from the history records were from good and medium sites, different aspects, elevations, inventory types and biogeoclimatic sub-zones. The review of biological factors

FIGURE 8: EXAMPLE DISTRIBUTION OF REGENERATION DELAYS CALCULATED FROM HISTORY RECORD DATA.
3-YEAR DELAY CLASSES

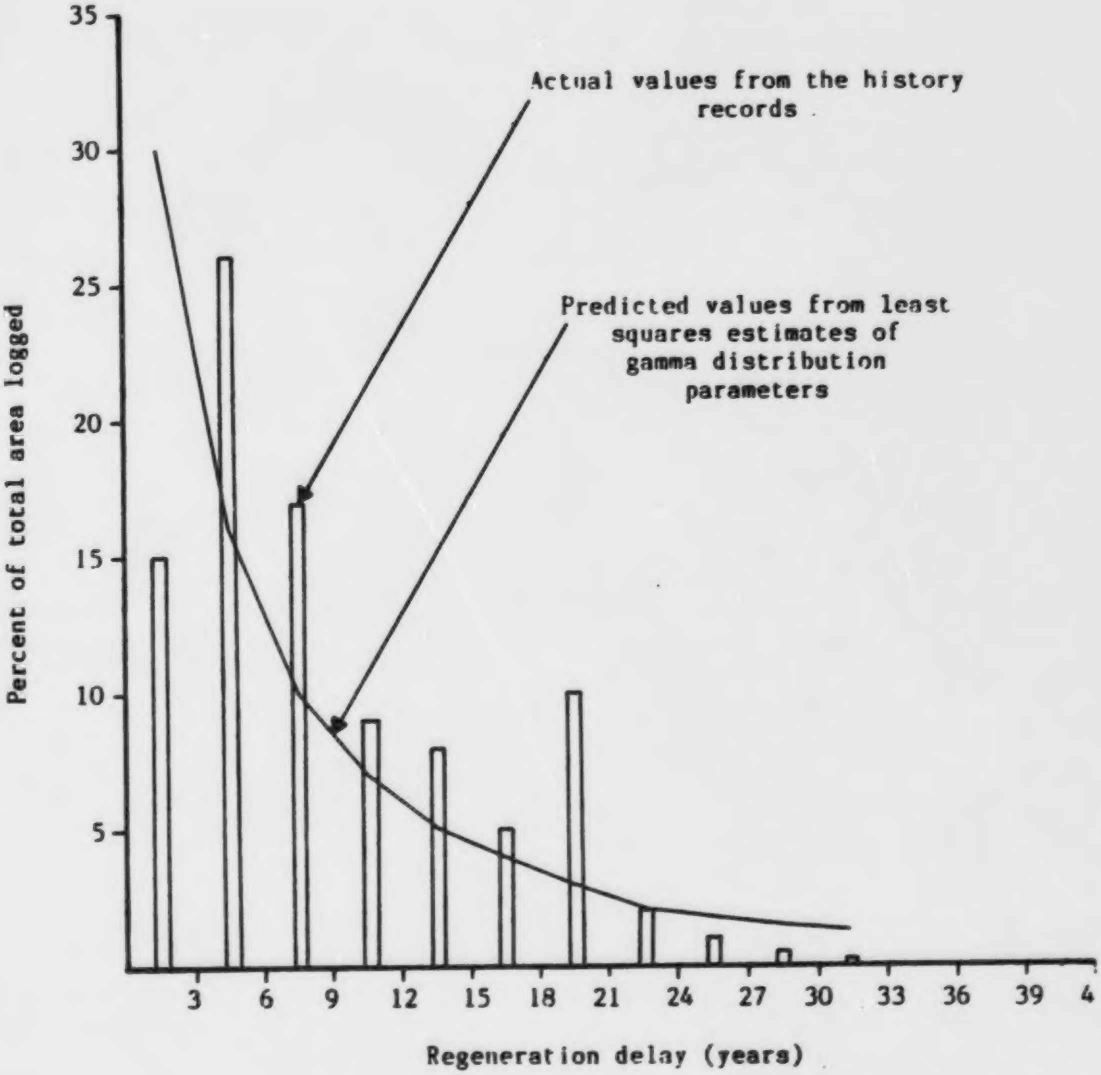
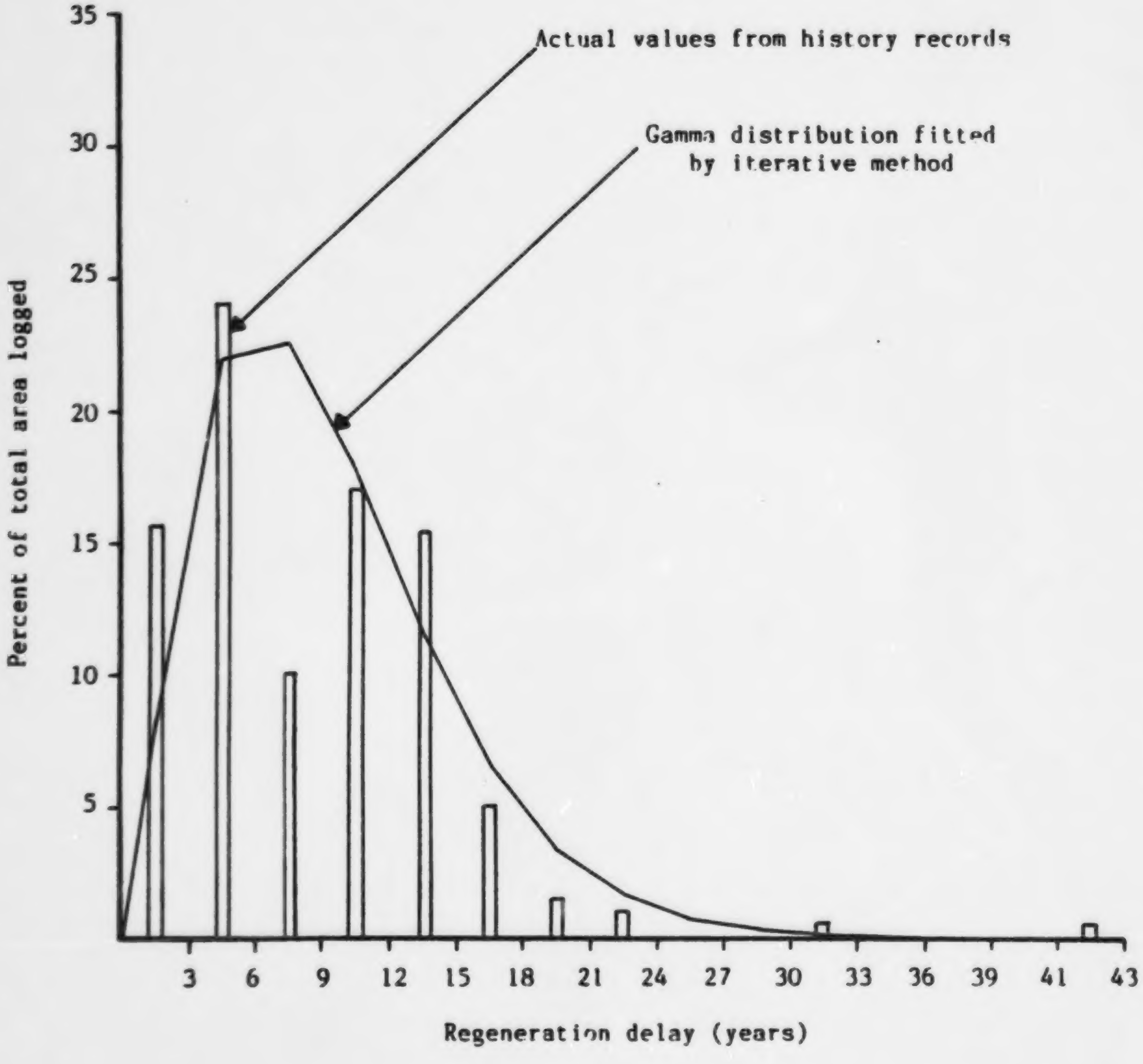


FIGURE 9: GAMMA DISTRIBUTION FITTED TO REGENERATION DELAYS FOR GROUP #6 USING AN ITERATIVE METHOD



at the beginning of this report showed that average regeneration delays are affected by different sets of biological conditions. Important questions for this project were:

(1) What biological factors in the history record data affect regeneration delays?

(2) Can the factors be used to group the regeneration delays in biological strata?

Before these questions could be answered, a considerable amount of data processing was necessary. In the History Record Data there were regeneration delays for:

- 13 biogeoclimatic subzones
- 17 inventory growth types
- 2 site classes
- 5 elevation classes
- 10 aspect classes

If these six factors were independent and occurred in all combinations the maximum possible number of biological streata would be 22,100 (13 x 17 x 2 x 5 x 10). There will be less than this number because, for example, each inventory growth type does not occur in each biogeoclimatic subzone or in each elevation class.

The first step in the stratification process was to carry out a simple one-way analysis of variance on each of the six factors listed above. This was followed by a Tukey's w test to determine which classes within a factor were significantly different. This procedure is also called the honestly significant difference procedure.

The procedure consists of computing:

$$w = q_{\infty} (p, n_2) S_X \tag{18}$$

where

$$q_{\infty} = \frac{\bar{X}_{max} - \bar{X}_{min}}{S_{\bar{X}}} \tag{19}$$

and X_{max} = maximum treatment mean
X_{min} = minimum treatment mean
$S_{\bar{X}}$ = standard error of the mean
p = number of treatments
n_2 = error degrees of freedom

w is used as the least significant difference to judge whether any two treatment means are significantly different.

Tukey's w procedure can be applied regardless of the significance of the treatment F ratio.

From the History Record Data six files were created by sorting the files by each of the six factors. Then, for each treatment class within a given factor the area regeneration delays were calculated. Then, one way analysis of variance was used to test the null hypothesis of no difference between treatment average regeneration delays.

The treatment classes used within each factor were the following.

Biogeoclimatic Sub-zone

These were; SBS, ESSF, BWBS, IDF, MS, ICH, CDF, CCPH, CWH, MH, PPBG, SBSW, SWB.

Inventory Growth Types

These were the 17 growth types defined by the MOFL by combining their 42 inventory type groups. The growth types are labelled A to Q. In the history records forest type is recorded using a different system to that used inthe provincial inventory. Because yield curves are based on the inventory system the history record forest type labels were converted to the 17 growth types by considering three species, location in theprovince and biogeolimatic subzone. The growth types are defined in Appendices 2 and 3.

Site Classes

These were good and medium.

Elevation Classes

These were; 0-500 m, 500-1000 m, 1000-1500 m, 1500-2000 m, 2000-2500 m.

Aspect Classes

These were; N, NE, NW, E, W, S, SE, SW, Flat, Variable.

ONE WAY ANALYSIS OF VARIANCE

Six one-way analyses of variance were carried out on the regeneration delays, one analysis for each factor. Each analysis of variance was followed by a comparison of means using Tukey's w procedure at the 5% level of significance. The results were not very helpful to the task of stratification. They are summarized below and then discussed.

The F ratio for Biogeoclimatic Sub-zone was not significant. Tukey's w procedure found that one sub-zone, the CCPH, was significantly different from the rest.

The F ratio for aspect class was not significant. Tukey's w procedure found no two means that were different.

A t-test found no significant difference between the average regeneration delay for good and medium site.

The F ratio for elevation class was significant at the 1% level. Tukey's w procedure showed this was entirely due to the mean for 2000-2500 m being significantly different from the rest. All other elevation classes were not significantly different.

The F ratio for aspect class was not significant. Tukey's w procedure found that no two means were significantly different.

By themselves the results of the one way analyses of variance did not allow the regeneration delays to be stratified. By itself, analysis of variance indicated that no biological factors affected regeneration delay. From the review of past work it is plain that these factors do affect regeneration delay. Reasons for the disappointing analysis of variance results were the confounding of effects and the sampling variation in the history record data. For example, the regeneration delays for a single aspect class included the effects of different inventory types, elevations, etc. These other effects increased the error variance and masked the effect of aspect itself. Furthermore, because the 'experiment' was not a planned experiment the confounding effect was different, and unknown, for the other aspect classes. The History Record Data contain a great deal of sampling error. One reason is that a proxy for regeneration delay had to be used because regeneration surveys are not carried out each year on the same area. Another reason is unequal sample sizes found in the different categories. In some categories the sample size might be 20 and in others it might be three.

A FACTORIAL ANALYSIS OF VARIANCE

A more complex statistical design with interactions between factors should allow the effect of each main factor on regeneration delay to be separated from the others. The available designs were severely limited in this project because the 'experiment' was unplanned. Therefore, the analysis of variance was designed after the fact to fit the available data. This forced compromises to be made between the ideal experimental design and that actually possible. The following procedure was used to develop a statistical design producing a reasonable grouping of biological conditions for natural regeneration delays.

First, biogeoclimatic sub-zones were dropped as a factor because they overlap with forest growth type. Forest growth and yield information is only available by forest growth type. When the mean delays by elevation class were examined after one way analysis, only the extreme high elevation class was different from the rest. Very few areas in the data fall into this class so elevation was also dropped.

This left 17 growth types, 10 aspect classes and two site classes. The 17 growth types were reduced to 10 by: dropping the deciduous types O, P and Q; combining the hemlock types F and G; combining the interior Douglas-fir and larch types C and D; and combining the lodgepole pine mixed types M and N. The aspect classes were reduced to five by combining N, NE, NW and S, SE, SW and F,V.

The remaining factors were forest growth type (10 treatment levels), aspect (five treatment levels) and site (two treatment levels). This enabled a factorial analysis of variance to be used. To obtain an estimate of error variance more than one observation per cell was required. This was achieved by combining good and medium sites to give two observations per cell.

The resulting design was an 10 x 5 factorial with two observations per cell. This design required 100 average regeneration delays to be calculated from 100 groupings of the original 3,700 delays. The two factors were forest growth type and aspect. Forest growth type was chosen for the following reasons.

(1) Seed source and seed distribution patterns are important determinants of regeneration delay.

(2) Forest type; like biogeoclimatic sub-zone, is an integrator of many environmental factors.

(3) Available growth and yield information is expressed in terms of forest type.

Aspect was chosen for the following reason.

(1) In studies of seed dispersal and natural regeneration establishment, aspect is almost always found to be an important factor.

The results of the factorial analysis of variance are shown in Table 5.

Table 5. ANOVA for Average Regeneration Delay

	Sum of Squares	**Deg. Freedom**	**Mean Square**	**F ratio**
Forest type (A)	116.61	9	12.96	1.70 (NS)
Aspect (B)	63.42	4	15.86	2.09 (NS)
AXB Interaction	324.88	36	9.02	1.19 (NS)
Error	380.07	50	7.60	

In Table 5 none of the F ratios are significant at the 5% level. Nevertheless, within a treatment, some means may be significantly different. The choice was made to examine the forest type means within each aspect class.

The next step in the analysis was to apply Tukey's w procedure to the forest type means within each aspect class. Table 6 shows the average regeneration delays for each forest type within each aspect.

Table 6. Average Regeneration Delays

Forest Type	N	S	E	W	F
AB	14.574	9.597	11.172	4.720	3.313
CD	5.806	6.948	7.958	6.575	7.859
E	9.369	10.132	7.5321	8.260	4.136
FG	11.938	9.940	15.501	11.255	6.641
H	4.950	9.552	7.703	8.463	7.630
I	9.527	9.627	8.362	6.527	5.585
J	8.578	9.833	9.624	9.864	11.248
K	8.343	9.252	9.235	9.634	9.634
L	7.473	6.958	7.380	7.016	9.659
MN	8.569	7.503	7.697	8.449	7.223

Using the results of the analysis of variance in Table 5, the honest significant difference was calculated to be 2.91 years for types within aspect. This was used to group the average regeneration delays within each aspect class. An example of this procedure is given for the means within the east aspect class. The means are listed in ascending order;

Type	Mean
L	7.380
E	7.531
MN	7.697
H	7.703
CD	7.958
I	8.362
K	9.235
J	9.624
AB	11.172
FG	15.501

The vertical lines join all means whose difference is less than 2.91. There are three sets, {L,E,MN,H,CD,I,K,J}, {I,K,J}, {AB,FG}. The group I,K,J, forms an intersection with another set. The selected grouping was {L,E,MN,H,CD} {I,J,K} {AB,FG}. The first and third groups do not intersect with any others. The second group {I,J,K} is distinguished by being an intersection of two sets.

A similar grouping process was carried out for all aspect classes.

For the regeneration delays distinctions between coast and interior were implicit in the inventory growth types. For those growth types occurring on both the coast and the interior, there were not enough data available to fill all the required combinations of aspect class and inventory growth type. Accordingly differences between coast and interior for regeneration delays in the same type/aspect combination could not be examined.

RESULTS OF REGENERATION DELAY GROUPING

The grouping procedure described above produced 19 combinations of growth type and aspect whose average regeneration delay was considered to be different. These 19 groups are shown in Table 7.

Table 7. Growth type/aspect groupings for average regeneration delay

ASPECT CLASS									
North	**#**	**South**	**#**	**East**	**#**	**West**	**#**	**Flat**	**#**
H	1	CD L	5	L E MN H CD	8	AB	11	AB	15
CD L K MN J	2	MN K H AB I J	6	I K J	9	I CD L E MN H	12	E I	16
E I FG	3	FG E	7	AB FG	10	K J	13	FG MN H CD	17
AB	4					FG	14	K L	18
								J	19

Next, for all 19 groups the distribution of regeneration delays in the data base was calculated, using a three-year class width and the specially written software. Then the gamma distribution pdf was fitted to these data for each group using the iterative method described in previous sections of the report. The areas under the gamma pdf corresponding to each three-year class were obtained by integrating the pdf using Simpson's rule. These areas were estimates of the proportion of all logged areas regenerating naturally in each three-year interval. Following this a paired t-test was used to test the goodness of fit of this predicted distribution of regeneration delays to the actual distribution calculated from the History Record Data. Because the predicted and observed regeneration delay distributions were proportions, the arcsine transformation was applied to the data. The paired t-test used the transformed data. The null hypothesis was that the mean difference between pairs of observed and predicted proportions was equal to zero. This was tested by comparing the calculated t-statistic with the 0.05% t distribution value. If the calculated value was less than the two-sided 0.05% value then the null hypothesis was accepted and the predicted distribution was judged not significantly different from the observed distribution. In other words, if the null hypothesis was accepted then the predicted distribution was a good fit. All the distributions were a statistically significant fit as shown in Table 8.

Table 8. Parameters of fitted gamma distributions and goodness of fit statistics

Group #	a	b	Calculated t-value	Tabulated $t_{0.05}$
1	3.00	1.25	0.2788	2.10
2	3.20	1.30	1.4997	2.10
3	3.10	1.50	0.2497	2.10
4	1.25	0.75	1.2701	2.06
5	3.10	1.50	1.0020	2.13
6	3.00	1.10	0.1352	2.09
7	3.00	1.40	1.2755	2.09
8	2.20	1.10	1.8085	2.07
9	1.00	0.80	1.2182	2.07
10	1.25	0.50	1.2747	2.04
11	1.40	1.10	0.8551	2.11
12	3.00	1.50	0.4011	2.13
13	3.00	1.00	1.4020	2.07
14	1.70	0.80	1.3949	2.06
15	1.40	1.30	0.8414	2.13
16	3.00	1.70	0.7057	2.16
17	3.00	1.50	0.6669	2.13
18	3.00	1.40	0.1825	2.10
19	1.50	1.00	1.1458	2.09

The 19 different regeneration delay distributions are shown in Appendix 1.

ESTIMATING BACKLOG NATURAL YIELDS

A set of yield tables for untreated backlog stands was developed. These tables were produced from Ek-Payandeh yield functions modified to represent low initial stocking and to include the regeneration delays estimated earlier for 19 forest type/aspect groups. A separate yield table was constructed for forest types A to N in each aspect class. A separate yield table was also constructed for good and medium site. The entire process was carried out for the Coast and the Interior of B.C.

GROUPING YIELD FUNCTIONS

For each forest growth type the MOFL has several different Ek-Payandeh yield functions. This is because the province is divided into 12 different geographic zones called Forest Inventory Zones (FIZ). The process of modifying the yield functions began with each individual yield curve for each forest type in each FIZ. The same yield function often turns up in more than one FIZ zone. Each Ek-Payandeh curve covers all sites because site index is used as one of the independent variables. the total number of different Ek-Payandeh functions used was 130.

These 130 curves were then listed by forest growth type and separated into Coast and Interior.

INCLUDING STOCKING LEVEL

The relative volume factor for every forest growth type in the Coast and Interior regions was derived from Inventory Report #3 using the Z-value method described earlier in the report. Then, for each of the 130 Ek-Payandeh functions a new value of b_3, representing untreated backlog stands, was calculated. The method used was that described earlier in the report (equation (6)).

INCLUDING REGENERATION DELAYS

Special computer software was developed to combine several Ek-Payandeh functions into one yield table. The parameter sets for all curves in a given forest type, including the new b_3 values, were input to the program. In addition the correct regeneration delay for untreated backlog stands was incorporated into the yield function. This was done by replacing age with (age minus regeneration delay). The Ek-Payandeh function with regeneration delay included is:

$$\text{Volume} = b_1 SI^{b_2}\left(1-e^{b_3(Age-t_o)}\right)^{b_4 SI^{b_5}} \qquad (18)$$

where: t_o = regeneration delay

For each of the 19 regeneration delay distributions the History Record Data for FRDA plantations were retrieved. Then the average delay since logging was calculated for each set of FRDA plantations. If these backlog areas had not been replanted, how much longer would the regeneration delay have been? The answer to this question was estimated by using the 19 distributions in Appendix 1 as follows.

Theoretically, the expected delay for backlog sites should be calculated using conditional probability. This could be done by saying 'given the known delay to rehabilitation planting, what is the average delay of the remainder of the regeneration delay distribution? ' This approach was attempted, but problems were encountered with the calculation of the known delay from the date of logging to the rehabilitation planting. The history record data used contained a surprisingly low number of actual plantations established by the FRDA program. Furthermore, these data were unevenly distributed across the 19 regeneration delay types. This produced a large variation in the regeneration delay up to rehabilitation. The minimum calculated from the history records was two years for group #14 and the maximum was 31 years for group #15. The variation in between these extremes appeared to be random. This variation in turn affected the weighted average delay of the right hand tail of the distributions. These delays based on conditional probability are shown in the 'average' delay column of table 9.

Another, simpler way of estimating the delay for untreated backlog land was also applied. For each distribution, the maximum regeneration delay was identified. Then the assumption was made that the mid point between the actual FRDA delay and the maximum delay was a reasonable estimate of the regeneration delay for untreated backlog land. These estimates are shown in the 'mid point' delay column of table 9. The results of table 9 were discussed with Ministry staff. The mid point column corresponded with field staff estimates better than the average column. For this reason, and because of the variation in the history record data for known delays to rehabilitation, the simpler mid point method was used.

Table 9. Estimated regeneration delays for untreated backlog forest land

Group	Delay (years) Mid point	Average
1	47	26
2	34	16
3	29	13
4	32	14
5	30	15
6	37	14
7	31	16
8	35	14
9	40	14
10	58	23
11	34	13
12	28	13
13	39	13
14	42	11
15	40	33
16	28	18
17	30	15
18	30	13
19	36	16

The computer program calculated yields from each parameter set and produced a combined yield table containing the average yields of the component parameter sets. A yield table was produced for each forest type on good and medium sites.

RESULTS

The estimated distributions of regeneration delays for each of the 19 aspect and forest-type groupings are presented in Appendix 1. The yield tables are presented in Appendix 2 (Coastal tables) and Appendix 3 (Interior tables) of this report.

The reference heights for good and medium sites were taken from Inventory Report #1 (MOFL, 1981). For lodgepole pine and interior spruce types these reference heights were converted to the equivalent value at breast height age 50. All other reference heights represent height at total age 100. Table 10 shows the reference heights used to produce the yield tables. For both coast and interior a 30 cm stump and 10 cm top diameter inside bark was used. The minimum dbh outside bark was 22.5 cm for the coast and 17.5 cm for the interior.

Table 10: Site index[1] reference heights

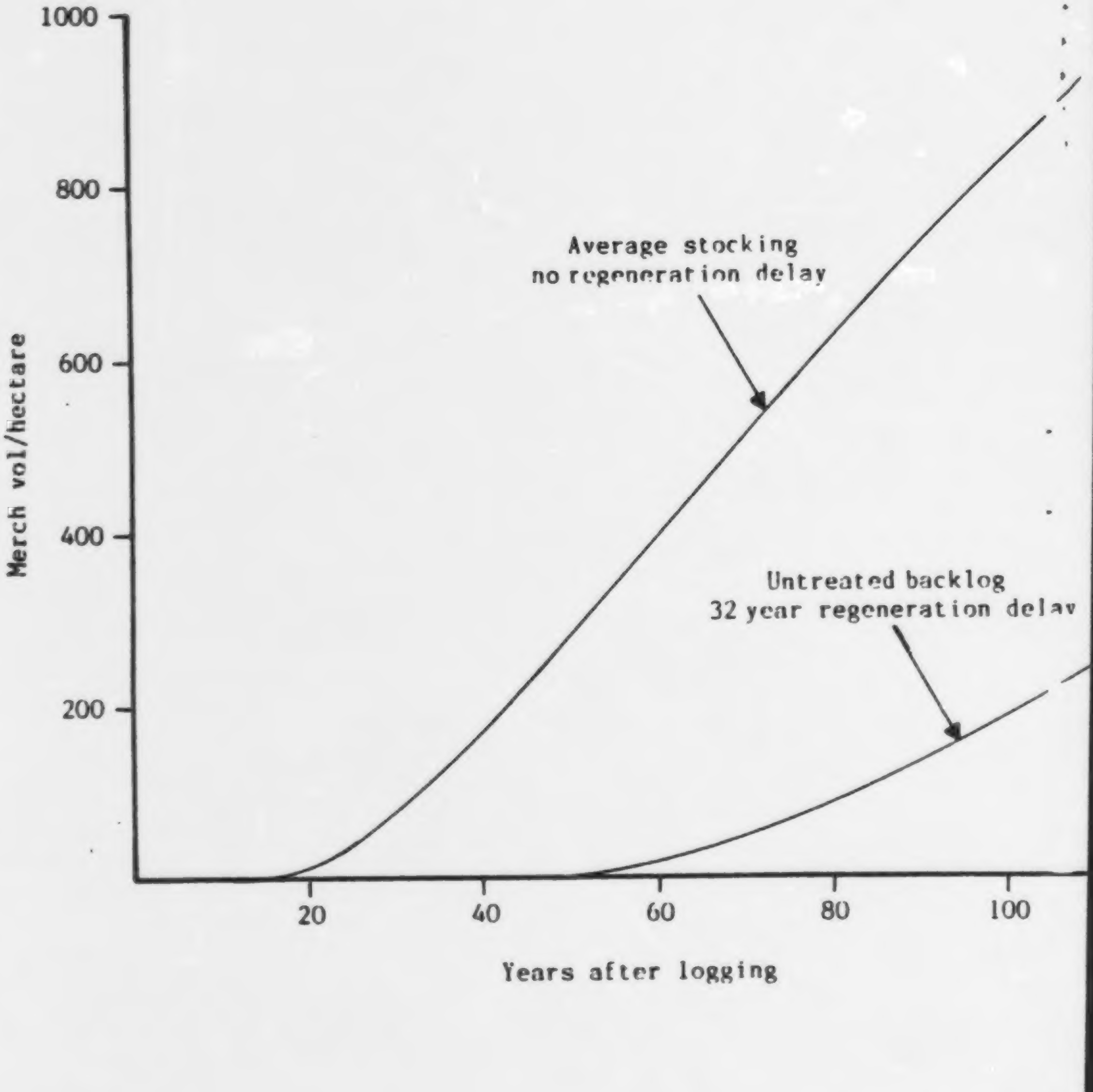
	GOOD		MEDIUM	
	Coast	**Interior**	**Coast**	**Interior**
A	48.8		36.6	
B	48.8	30.5	36.6	24.4
C		30.5		24.4
D		30.5		24.5
E	45.7	33.6	33.5	27.5
F	45.7	33.6	33.5	27.5
G	45.7	33.6	33.5	27.5
H	45.7	28.7	33.5	22.6
I	45.7	23.3	33.5	16.2
J	45.7	23.3	33.5	16.2
K	45.7	23.3	33.5	16.2
L	24.8	24.8	17.7	17.7
M	24.8	24.8	17.7	17.7
N	24.8	24.8	17.7	17.7

[1] Reference age is 100 years total age except for lodgepole pine types and interior spruce types where the reference age is 50 years breast height age.

DISCUSSION OF RESULTS

The general effect of the modifications made to the Ek-Payandeh yield functions are illustrated by Figure 10. This shows a single MOFL yield curve (curve #4080) before and after modification.

FIGURE 10: MOFL EK-PAYANDEH CURVE #6080 DOUGLAS FIR GROWTH TYPE - GOOD SITE (SI 48.8 (100 YR)) AVERAGE STOCKING, NO REGENERATION DELAY COMPARED WITH LOW STOCKED UNTREATED BACKLOG STAND, 32 YEAR REGENERATION DELAY



The regeneration delay distributions of Appendix 1 were generated by integrating areas under the gamma probability density function. The parameters of the gamma distributions were estimated by an iterative procedure followed by a statistical goodness of fit test. Appendix 1 makes the best possible use of the regeneration survey data from the History Record System. However, those data are distributed unevenly across different forest type, aspect and site classes. The history records only allow an approximate estimate of regeneration delay to be made. Even so, Appendix 1 represents the first systematic attempt in B.C. to estimate the distribution of natural regeneration delays after logging.

Appendices 2 and 3 contain the yield tables for untreated backlog forest lands. They are derived from Ek-Payandeh yield functions modified for backlog regeneration delays and levels of stocking. The backlog regeneration delays were derived from the time since logging for those sites replanted by FRDA and the range of the distributions in Appendix 1. The level of stocking in backlog stands was assumed to be the low 10% of the stocking levels found in the provincial inventory plots for a given age. The number of yield tables could be reduced by a factor of 5 if all aspects are pooled. Aspect was not a significant factor in the analysis of variance in this study. However, in the review of past work aspect is considered important by several researchers. Basic environmental principles also imply that aspect may be an important factor in affecting regeneration delays.

This report represents a systematic attempt to make the best use of available data. These data are incomplete and are not abundant. The yields in Appendices 2 and 3 are strongly affected by the assumptions made in this report about regeneration delays and the level of stocking on untreated backlog lands. Initial volumes in the tables will occur later than the estimated regeneration delay because merchantable volumes, not gross, are shown in the tables. The lack of information means that the assumptions made in the report cannot be tested rigorously. The systematic approach used by the consultant lends itself to rigorous testing when good data are collected. In spite of the effort spent by government on forestry data collection, some fundamental information is still lacking. In the meantime these yield estimates for untreated backlog lands are the best available.

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APPENDIX 1

REGENERATION DELAY DISTRIBUTIONS

GROUP 1	**TYPE H, NORTH ASPECT**
0 - 3	0.0382675
3 - 6	0.2041554
6 - 9	0.2738090
9 - 12	0.2187418
12 - 15	0.1347758
15 - 18	0.0711051
18 - 21	0.0338418
21 - 24	0.0149680
24 - 27	0.0062670
27 - 30	0.0025145
30 - 33	0.0009752
33 - 36	0.0003680
36 - 39	0.0001356
39 - 42	0.0000489
42 - 45	0.0000175
45 - 48	0.0000061
48 - 51	0.0000021
51 - 54	0.0000007
54 - 57	0.0000002

GROUP 2	**TYPES C,D,J,K,L,M, NORTH ASPECT**
0 - 3	0.0330758
3 - 6	0.1962697
6 - 9	0.2764025
9 - 12	0.2247720
12 - 15	0.1386335
15 - 18	0.0724706
18 - 21	0.0339426
21 - 24	0.0147015
24 - 27	0.0060058
27 - 30	0.0023445
30 - 33	0.0008827
33 - 36	0.0003226
36 - 39	0.0001150
39 - 42	0.0000402
42 - 45	0.0000138
45 - 48	0.0000047
48 - 51	0.0000015
51 - 54	0.0000005
54 - 57	0.0000001

GROUP 3	TYPES E,F,G,I, NORTH ASPECT
0 - 3	0.0537229
3 - 6	0.2543382
6 - 9	0.2965345
9 - 12	0.2047814
12 - 15	0.1088572
15 - 18	0.0495053
18 - 21	0.0203004
21 - 24	0.0077338
24 - 27	0.0027887
27 - 30	0.0009635
30 - 33	0.0003217
33 - 36	0.0001045
36 - 39	0.0000332
39 - 42	0.0000103
42 - 45	0.0000032
45 - 48	0.0000009
48 - 51	0.0000003

GROUP 4	**TYPES A,B, NORTH ASPECT**
0 - 3	0.0433237
3 - 6	0.1427821
6 - 9	0.1839690
9 - 12	0.1741909
12 - 15	0.1417721
15 - 18	0.1054609
18 - 21	0.0739084
21 - 24	0.0496441
24 - 27	0.0323038
27 - 30	0.0205087
30 - 33	0.0127667
33 - 36	0.0078204
36 - 39	0.0047268
39 - 42	0.0028248
42 - 45	0.0016718
45 - 48	0.0009813
48 - 51	0.0005717
51 - 54	0.0003309
54 - 57	0.0001904
57 - 60	0.0001090
60 - 63	0.0000622
63 - 66	0.0000353
66 - 69	0.0000199
69 - 72	0.0000114
72 - 75	0.0000062
75 - 78	0.0000035
78 - 81	0.0000020
81 - 84	0.0000011
84 - 87	0.0000006
87 - 90	0.0000004

GROUP 5	**TYPES C,D,L, SOUTH ASPECT**
0 - 3	0.0583306
3 - 6	0.2745897
6 - 9	0.3060365
9 - 12	0.1982931
12 - 15	0.0979694
15 - 18	0.0411783
18 - 21	0.0155491
21 - 24	0.0054407
24 - 27	0.0017983
27 - 30	0.0005687
30 - 33	0.0001736
33 - 36	0.0000514
36 - 39	0.0000149
39 - 42	0.0000042
42 - 45	0.0000011
45 - 48	0.0000004

GROUP 6 TYPES A,H,I,J,K,M, SOUTH ASPECT

0 - 3	0.0257408
3 - 6	0.1549061
6 - 9	0.2390144
9 - 12	0.2208906
12 - 15	0.1577487
15 - 18	0.0965484
18 - 21	0.0533324
21 - 24	0.0273851
24 - 27	0.0133139
27 - 30	0.0062039
30 - 33	0.0027945
33 - 36	0.0012244
36 - 39	0.0005243
39 - 42	0.0002201
42 - 45	0.0000910
45 - 48	0.0000370
48 - 51	0.0000148
51 - 54	0.0000059
54 - 57	0.0000023
57 - 60	0.0000010
60 - 63	0.0000004

GROUP 7 TYPES E,F,G, SOUTH ASPECT

0 - 3	0.0537229
3 - 6	0.2543382
6 - 9	0.2965345
9 - 12	0.2047814
12 - 15	0.1088572
15 - 18	0.0495053
18 - 21	0.0203004
21 - 24	0.0077338
24 - 27	0.0027887
27 - 30	0.0009635
30 - 33	0.0003217
33 - 36	0.0001045
36 - 39	0.0000332
39 - 42	0.0000103
42 - 45	0.0000032
45 - 48	0.0000009
48 - 51	0.0000003

GROUP 8 TYPES C,D,E,H,L,M, EAST ASPECT

0 - 3	0.0164631
3 - 6	0.1233285
6 - 9	0.2192988
9 - 12	0.2237240
12 - 15	0.1722139
15 - 18	0.1119447
18 - 21	0.0650249
21 - 24	0.0348598
24 - 27	0.0175993
27 - 30	0.0084804
30 - 33	0.0039369
33 - 36	0.0017729
36 - 39	0.0007784
39 - 42	0.0003345
42 - 45	0.0001411
45 - 48	0.0000587
48 - 51	0.0000240
51 - 54	0.0000097
54 - 57	0.0000039
57 - 60	0.0000015
60 - 63	0.0000006
63 - 66	0.0000002

GROUP 9	**TYPES I,J,K, EAST ASPECT**
0 - 3	0.0365589
3 - 6	0.2053994
6 - 9	0.2791104
9 - 12	0.2214051
12 - 15	0.1340103
15 - 18	0.0690035
18 - 21	0.0319142
21 - 24	0.0136743
24 - 27	0.0055337
27 - 30	0.0021421
30 - 33	0.0008004
33 - 36	0.0002906
36 - 39	0.0001030
39 - 42	0.0000358
42 - 45	0.0000123
45 - 48	0.0000042
48 - 51	0.0000014
51 - 54	0.0000005
54 - 57	0.0000001

GROUP 10	**TYPES A,B,F,G, EAST ASPECT**
0 - 3	0.0311017
3 - 6	0.1025955
6 - 9	0.1417900
9 - 12	0.1479964
12 - 15	0.1345911
15 - 18	0.1127712
18 - 21	0.0894911
21 - 24	0.0683222
24 - 27	0.0506726
27 - 30	0.0367472
30 - 33	0.0261744
33 - 36	0.0183720
36 - 39	0.0127388
39 - 42	0.0087421
42 - 45	0.0059465
45 - 48	0.0040139
48 - 51	0.0026914
51 - 54	0.0017939
54 - 57	0.0011895
57 - 60	0.0007849
60 - 63	0.0005159
63 - 66	0.0003377
66 - 69	0.0002204
69 - 72	0.0001432
72 - 75	0.0000929
75 - 78	0.0000601
78 - 81	0.0000388
81 - 84	0.0000250
84 - 87	0.0000160
87 - 90	0.0000103
90 - 93	0.0000066
93 - 96	0.0000042
96 - 99	0.0000027

GROUP 11	**TYPES A,B, WEST ASPECT**
0 - 3	0.1999453
3 - 6	0.3341347
6 - 9	0.2338778
9 - 12	0.1263207
12 - 15	0.0602249
15 - 18	0.0266777
18 - 21	0.0112578
21 - 24	0.0045900
24 - 27	0.0018240
27 - 30	0.0007105
30 - 33	0.0002725
33 - 36	0.0001031
36 - 39	0.0000386
39 - 42	0.0000143
42 - 45	0.0000053
45 - 48	0.0000020
48 - 51	0.0000007
51 - 54	0.0000003

GROUP 12 TYPES E,C,H,I,L,M, WEST ASPECT

0 - 3	0.0656395
3 - 6	0.2871269
6 - 9	0.3049366
9 - 12	0.1910926
12 - 15	0.0920589
15 - 18	0.0379191
18 - 21	0.0140792
21 - 24	0.0048557
24 - 27	0.0015848
27 - 30	0.0004956
30 - 33	0.0001498
33 - 36	0.0000440
36 - 39	0.0000126
39 - 42	0.0000036
42 - 45	0.0000010
45 - 48	0.0000002

GROUP 13	TYPES J,K, WEST ASPECT
0 - 3	0.0189875
3 - 6	0.1238886
6 - 9	0.2098917
9 - 12	0.2137619
12 - 15	0.1684444
15 - 18	0.1138222
18 - 21	0.0694386
21 - 24	0.0393855
24 - 27	0.0211536
27 - 30	0.0108904
30 - 33	0.0054201
33 - 36	0.0026241
36 - 39	0.0012415
39 - 42	0.0005761
42 - 45	0.0002628
45 - 48	0.0001182
48 - 51	0.0000525
51 - 54	0.0000231
54 - 57	0.0000100
57 - 60	0.0000042
60 - 63	0.0000018
63 - 66	0.0000008
66 - 69	0.0000004

GROUP 14 TYPES, F,G, WEST ASPECT

0 - 3	0.0742562
3 - 6	0.2070205
6 - 9	0.2252598
9 - 12	0.1809774
12 - 15	0.1253647
15 - 18	0.0795310
18 - 21	0.0476007
21 - 24	0.0273345
24 - 27	0.0152184
27 - 30	0.0082719
30 - 33	0.0044107
33 - 36	0.0023153
36 - 39	0.0011996
39 - 42	0.0006148
42 - 45	0.0003120
45 - 48	0.0001572
48 - 51	0.0000786
51 - 54	0.0000390
54 - 57	0.0000193
57 - 60	0.0000095
60 - 63	0.0000047
63 - 66	0.0000022
66 - 69	0.0000011
69 - 72	0.0000005
72 - 75	0.0000004

GROUP 15	TYPES A,B, FLAT ASPECT
0 - 3	0.2624641
3 - 6	0.3710852
6 - 9	0.2140339
9 - 12	0.0949011
12 - 15	0.0370978
15 - 18	0.0134667
18 - 21	0.0046556
21 - 24	0.0015548
24 - 27	0.0005060
27 - 30	0.0001614
30 - 33	0.0000507
33 - 36	0.0000157
36 - 39	0.0000048
39 - 42	0.0000015
42 - 45	0.0000005
45 - 48	0.0000001

GROUP 16	TYPES E,I, FLAT ASPECT
0 - 3	0.0931849
3 - 6	0.3484557
6 - 9	0.3070899
9 - 12	0.1584633
12 - 15	0.0626971
15 - 18	0.0211851
18 - 21	0.0064486
21 - 24	0.0018227
24 - 27	0.0004874
27 - 30	0.0001249
30 - 33	0.0000309
33 - 36	0.0000074
36 - 39	0.0000018
39 - 42	0.0000004

GROUP 17 TYPES C,D,F,G,H,M, FLAT ASPECT

0 - 3	0.0656395
3 - 6	0.2871269
6 - 9	0.3049366
9 - 12	0.1910926
12 - 15	0.0920589
15 - 18	0.0379191
18 - 21	0.0140792
21 - 24	0.0048557
24 - 27	0.0015848
27 - 30	0.0004956
30 - 33	0.0001498
33 - 36	0.0000440
36 - 39	0.0000126
39 - 42	0.0000036
42 - 45	0.0000010
45 - 48	0.0000002

GROUP 18	TYPES K,L, FLAT ASPECT
0 - 3	0.0537229
3 - 6	0.2543382
6 - 9	0.2965345
9 - 12	0.2047814
12 - 15	0.1088572
15 - 18	0.0495053
18 - 21	0.0203004
21 - 24	0.0077338
24 - 27	0.0027887
27 - 30	0.0009635
30 - 33	0.0003217
33 - 36	0.0001045
36 - 39	0.0000332
39 - 42	0.0000103
42 - 45	0.0000032
45 - 48	0.0000009
48 - 51	0.0000003

GROUP 19	**TYPE J, FLAT ASPECT**
0 - 3	0.0021848
3 - 6	0.0199666
6 - 9	0.0515780
9 - 12	0.0826515
12 - 15	0.1039269
15 - 18	0.1129289
18 - 21	0.1113231
21 - 24	0.1023661
24 - 27	0.0893463
27 - 30	0.0748837
30 - 33	0.0607597
33 - 36	0.0480095
36 - 39	0.0371060
39 - 42	0.0281478
42 - 45	0.0210133
45 - 48	0.0154707
48 - 51	0.0112529
51 - 54	0.0080976
54 - 57	0.0057721
57 - 60	0.0040794
60 - 63	0.0028611
63 - 66	0.0019929
66 - 69	0.0013793
69 - 72	0.0009493
72 - 75	0.0006499
75 - 78	0.0004427
78 - 81	0.0003003
81 - 84	0.0002027
84 - 87	0.0001365
87 - 90	0.0000915
90 - 93	0.0000611
93 - 96	0.0000407
96 - 99	0.0000271

APPENDIX 2

YIELD TABLES FOR UNTREATED BACKLOG LAND

COASTAL B.C.

YIELD TABLES FOR UNTREATED BACKLOG LAND

The yield tables in Appendices 2 and 3 represent the yields expected from untreated backlog forest land. Appendix 2 contains tables for coastal B.C. Appendix 3 contains tables for the interior. The forest types are those defined by the B.C. Ministry of Forests and Lands in Table 1.

Table 1. Forest Types

LETTER CODE	INVENTORY TYPE GROUPS
A	FPL, FDecid, Pw (coast), F
B	FC, FCy, FH, FS
C	FPL, FDecid (interior), FPy, Py, Pa
D	Pw (interior), FL, LF, L
E	C, CF, CH
F	H, HPL, HDecid
G	HF, HC, HB, HS
H	B, BH, BS
I	S
J	SF, SH, SC, SB
K	SPL, SDecid
L	PL
M	PLF, PLS, PLB
N	PLDecid

Age in the yield tables means years after logging. Volume is volume per hectare net decay only. Minimum dbh is 22.5 cm for the coastal tables and 17.5 cm for the interior. Stump height is 30 cm and top diameter inside bark is 10 cm. The yields in each table are combinations of several MOFL Ek-Payandeh functions modified for backlog regeneration delays and levels of stocking. The site index reference heights for the species in each growth type are presented in Table 10 of the main report.

Ten tables are presented for each forest type in each appendix. There are two tables each for north, south, east, west and flat aspects. Each forest type/aspect combination has one table for good site and one for medium.

COAST

GROWTH TYPE A, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.1	0.0
60	27.7	0.5
70	75.7	1.1
80	146.9	1.8
90	231.0	2.6
100	317.6	3.2
110	400.3	3.6
120	476.6	4.0
130	546.1	4.2

COAST

GROWTH TYPE A, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	13.2	0.2
70	48.4	0.7
80	108.9	1.4
90	188.1	2.1
100	274.5	2.7
110	359.7	3.3
120	439.3	3.7
130	512.1	3.9

COAST

GROWTH TYPE A, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	11.0	0.1
90	43.7	0.5
100	101.9	1.0
110	179.7	1.6
120	265.9	2.2
130	351.4	2.7

COAST

GROWTH TYPE A, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	1.6	0.0
60	21.2	0.4
70	64.0	0.9
80	131.2	1.6
90	213.7	2.4
100	300.5	3.0
110	384.2	3.5
120	461.8	3.8
130	532.7	4.1

COAST

GROWTH TYPE A, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.2	0.1
70	35.2	0.5
80	88.3	1.1
90	163.1	1.8
100	248.4	2.5
110	334.6	3.0
120	416.1	3.5
130	491.0	3.8

COAST

GROWTH TYPE A, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	10.0	0.2
70	35.1	0.5
80	74.1	0.9
90	121.6	1.4
100	172.1	1.7
110	221.8	2.0
120	268.8	2.2
130	312.8	2.4

COAST

GROWTH TYPE A, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual increment
10		
20		
30		
40		
50		
60	2.9	0.0
70	20.7	0.3
80	53.2	0.7
90	97.2	1.1
100	146.8	1.5
110	197.2	1.8
120	245.7	2.0
130	291.2	2.2

COAST

GROWTH TYPE A, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	1.8	0.0
90	18.2	0.2
100	49.3	0.5
110	92.4	0.8
120	141.7	1.2
130	192.2	1.5

COAST

GROWTH TYPE A, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	6.7	0.1
70	28.9	0.4
80	65.4	0.8
90	111.7	1.2
100	162.0	1.6
110	212.0	1.9
120	259.7	2.2
130	304.2	2.3

COAST

GROWTH TYPE A, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.0	0.0
70	13.8	0.2
80	42.0	0.5
90	83.1	0.9
100	131.6	1.3
110	182.2	1.7
120	231.4	1.9
130	277.9	2.1

COAST

GROWTH TYPE B, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	10.4	0.2
60	38.3	0.6
70	77.5	1.1
80	125.8	1.6
90	181.0	2.0
100	241.4	2.4
110	305.2	2.8
120	371.2	3.1
130	438.1	3.4

COAST

GROWTH TYPE B, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20	17.5	0.9
30	4.4	0.1
40	1.9	0.0
50	0.9	0.0
60	22.8	0.4
70	56.6	0.8
80	100.6	1.3
90	152.6	1.7
100	210.7	2.1
110	273.0	2.5
120	338.0	2.8
130	404.6	3.1

COAST

GROWTH TYPE B, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	20.1	0.3
90	52.7	0.6
100	95.8	1.0
110	147.1	1.3
120	204.7	1.7
130	266.6	2.1

COAST

GROWTH TYPE B, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	6.2	0.1
60	31.8	0.5
70	68.8	1.0
80	115.5	1.4
90	169.5	1.9
100	229.0	2.3
110	292.2	2.7
120	357.9	3.0
130	424.7	3.3

COAST

GROWTH TYPE B, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	15.0	0.2
70	45.3	0.6
80	86.5	1.1
90	136.3	1.5
100	192.8	1.9
110	253.9	2.3
120	318.3	2.7
130	384.5	3.0

COAST

GROWTH TYPE B, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	12.1	0.2
70	31.5	0.5
80	57.3	0.7
90	88.4	1.0
100	123.5	1.2
110	161.7	1.5
120	202.0	1.7
130	243.5	1.9

COAST

GROWTH TYPE B, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	5.1	0.0
70	20.9	0.3
80	43.7	0.5
90	72.3	0.8
100	105.5	1.1
110	142.3	1.3
120	181.6	1.5
130	222.6	1.7

COAST

GROWTH TYPE B, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	3.9	0.0
90	19.0	0.2
100	41.1	0.4
110	69.2	0.6
120	102.0	0.9
130	138.5	1.1

COAST

GROWTH TYPE B, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	9.1	0.2
70	27.1	0.4
80	51.7	0.6
90	81.8	0.9
100	116.2	1.2
110	153.9	1.4
120	193.8	1.6
130	235.1	1.8

COAST

GROWTH TYPE B, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	1.7	0.0
70	15.4	0.2
80	36.2	0.5
90	63.2	0.7
100	95.1	1.0
110	131.0	1.2
120	169.6	1.4
130	210.2	1.6

COAST

GROWTH TYPE E, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	1.7	0.0
50	9.7	0.2
60	28.5	0.5
70	63.4	0.9
80	120.0	1.5
90	201.3	2.2
100	306.0	3.1
110	429.4	3.9
120	564.5	4.7
130	704.1	5.4

COAST

GROWTH TYPE E, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.9	0.0
50	7.4	0.1
60	23.7	0.4
70	54.8	0.8
80	106.8	1.3
90	183.1	2.0
100	293.4	2.8
110	403.5	3.7
120	536.9	4.5
130	676.1	5.2

COAST

GROWTH TYPE E, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.2	0.0
50	3.9	0.0
60	15.7	0.3
70	40.2	0.6
80	83.2	1.0
90	149.6	1.7
100	240.6	2.4
110	353.5	3.2
120	482.4	4.0
130	620.2	4.8

COAST

GROWTH TYPE E, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	2.1	0.0
50	11.1	0.2
60	31.2	0.5
70	68.0	1.0
80	127.0	1.6
90	210.8	2.3
100	317.6	3.2
110	442.5	4.0
120	578.3	4.8
130	718.0	5.5

COAST

GROWTH TYPE E, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	2.1	0.0
50	11.1	0.2
60	31.2	0.5
70	68.0	1.0
80	127.0	1.6
90	210.8	2.3
100	317.6	3.2
110	442.5	4.0
120	578.3	4.8
130	718.0	5.5

COAST

GROWTH TYPE E, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.8	0.0
50	5.1	0.1
60	15.1	0.3
70	34.1	0.5
80	65.6	0.8
90	111.3	1.2
100	171.0	1.7
110	241.7	2.2
120	319.7	2.7
130	400.7	3.1

COAST

GROWTH TYPE B, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.5	0.0
50	3.9	0.0
60	12.5	0.2
70	29.4	0.4
80	59.2	0.7
90	101.0	1.1
100	158.0	1.6
110	226.8	2.1
120	303.7	2.5
130	384.5	3.0

COAST

GROWTH TYPE E, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	2.0	0.0
60	8.3	0.1
70	21.4	0.3
80	45.1	0.6
90	82.1	0.9
100	133.6	1.3
110	198.1	1.8
120	272.3	2.3
130	352.0	2.7

COAST
GROWTH TYPE E, WEST ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	1.1	0.0
50	5.8	0.1
60	16.6	0.3
70	36.7	0.5
80	69.5	0.9
90	116.7	1.3
100	177.6	1.8
110	249.2	2.3
120	327.7	2.7
130	408.9	3.1

COAST
GROWTH TYPE E, FLAT ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	1.1	0.0
50	5.8	0.1
60	16.6	0.3
70	36.7	0.5
80	69.5	0.9
90	116.7	1.3
100	177.6	1.8
110	249.2	2.3
120	327.7	2.7
130	408.9	3.1

COAST

GROWTH TYPE F, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	2.5	0.0
60	99.3	1.7
70	183.9	2.6
80	267.8	3.3
90	350.4	3.9
100	430.4	4.3
110	507.0	4.6
120	579.6	4.8
130	647.9	5.0

COAST

GROWTH TYPE F, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	82.0	1.4
70	167.1	2.4
80	251.1	3.1
90	334.0	3.7
100	414.6	4.1
110	492.0	4.5
120	565.4	4.7
130	634.6	4.9

COAST

GROWTH TYPE F, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	90.7	1.5
70	175.5	2.5
80	259.5	3.2
90	342.2	3.8
100	422.5	4.2
110	499.5	4.5
120	572.5	4.8
130	641.2	4.9

COAST

GROWTH TYPE F, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	10.8	0.2
70	57.2	0.8
80	107.4	1.3
90	160.7	1.8
100	215.4	2.2
110	270.0	2.5
120	323.6	2.7
130	375.3	2.9

COAST

GROWTH TYPE F, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	1.8	0.0
70	47.6	0.7
80	97.1	1.2
90	149.9	1.7
100	204.4	2.0
110	259.2	2.4
120	313.0	2.6
130	365.1	2.8

COAST

GROWTH TYPE F, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90	15.3	0.2
100	62.0	0.6
110	112.6	1.0
120	166.1	1.4
130	220.8	1.7

COAST

GROWTH TYPE F, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	42.9	0.5
90	92.0	1.0
100	144.5	1.4
110	198.9	1.8
120	253.7	2.1
130	307.7	2.4

COAST

GROWTH TYPE F, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	6.3	0.1
70	52.4	0.7
80	102.2	1.3
90	155.3	1.7
100	209.9	2.1
110	264.6	2.4
120	318.3	2.7
130	370.2	2.8

COAST

GROWTH TYPE G, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	40.8	0.8
60	107.0	1.8
70	185.7	2.7
80	271.0	3.4
90	357.7	4.0
100	442.3	4.4
110	522.5	4.8
120	597.3	5.0
130	666.3	5.1

COAST

GROWTH TYPE G, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	29.1	0.6
60	92.6	1.5
70	169.3	2.4
80	253.7	3.2
90	340.5	3.8
100	425.7	4.3
110	506.9	4.6
120	582.8	4.9
130	652.9	5.0

COAST

GROWTH TYPE G, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	46.7	0.6
90	114.4	1.3
100	134.0	1.9
110	279.7	2.5
120	366.3	3.1
130	450.5	3.5

COAST

GROWTH TYPE G, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	23.3	0.4
70	85.6	1.2
80	161.1	2.0
90	245.1	2.7
100	331.8	3.3
110	417.3	3.9
120	499.0	4.2
130	575.5	4.4

COAST

GROWTH TYPE G, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	34.9	0.7
60	99.7	1.7
70	177.4	2.5
80	262.3	3.3
90	349.1	3.9
100	434.0	4.3
110	514.7	4.7
120	590.1	4.9
130	659.6	5.1

COAST

GROWTH TYPE G, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	5.9	0.1
60	28.6	0.5
70	65.5	0.9
80	114.1	1.4
90	170.4	1.9
100	230.4	2.3
110	291.1	2.6
120	350.3	2.9
130	406.7	3.1

COAST

GROWTH TYPE G, SOUTH ASPECT

MEDIUM SITE

Age	**Volume (m^3/ha)**	**Mean Annual Increment**
10		
20		
30		
40		
50	3.0	0.0
60	22.9	0.4
70	57.1	0.8
80	103.7	1.3
90	158.7	1.8
100	218.3	2.2
110	279.1	2.5
120	339.7	2.8
130	395.7	3.0

COAST

GROWTH TYPE G, EAST ASPECT

MEDIUM SITE

Age	**Volume (m^3/ha)**	**Mean Annual Increment**
10		
20		
30		
40		
50		
60		
70		
80	7.5	0.0
90	31.7	0.4
100	69.9	0.7
110	119.5	1.1
120	176.3	1.5
130	236.5	1.8

COAST

GROWTH TYPE G, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	1.7	0.0
70	20.3	0.3
80	53.1	0.7
90	98.6	1.1
100	153.0	1.5
110	212.2	1.9
120	273.0	2.3
130	332.8	2.6

COAST

GROWTH TYPE G, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.4	0.0
60	25.7	0.4
70	61.3	0.9
80	108.9	1.4
90	164.6	1.8
100	224.4	2.2
110	285.1	2.6
120	344.5	2.9
130	401.2	3.1

COAST

GROWTH TYPE H, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	3.5	0.0
80	41.4	0.5
90	107.6	1.2
100	205.0	2.0
110	323.5	2.9
120	450.1	3.8
130	574.1	4.4

COAST

GROWTH TYPE H, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	3.5	0.0
70	41.4	0.6
80	107.6	1.3
90	205.0	2.3
100	323.5	3.2
110	450.1	4.1
120	574.1	4.8
130	689.6	5.3

COAST

GROWTH TYPE H, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	9.6	0.2
70	52.1	0.7
80	124.9	1.6
90	227.4	2.5
100	348.6	3.5
110	475.3	4.3
120	599.0	5.0
130	711.5	5.5

COAST

GROWTH TYPE H, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	0.4	0.0
60	36.6	0.6
70	99.5	1.4
80	194.1	2.4
90	311.1	3.5
100	437.4	4.4
110	562.0	5.1
120	678.6	5.7
130	784.3	6.0

COAST

GROWTH TYPE H, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	27.7	0.5
70	84.3	1.2
80	172.9	2.2
90	285.6	3.2
100	412.0	4.1
110	537.6	4.9
120	656.1	5.5
130	764.1	5.9

COAST

GROWTH TYPE H, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	4.5	0.0
70	5.8	0.0
80	18.5	0.2
90	45.0	0.5
100	92.2	0.9
110	159.4	1.4
120	240.1	2.0
130	326.3	2.5

COAST

GROWTH TYPE H, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.5	0.0
60	5.8	0.0
70	18.5	0.3
80	45.0	0.6
90	92.2	1.0
100	159.4	1.6
110	240.1	2.2
120	326.3	2.7
130	412.0	3.2

COAST

GROWTH TYPE H, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.6	0.1
70	22.4	0.3
80	52.7	0.7
90	104.1	1.2
100	174.7	1.7
110	257.1	2.3
120	343.7	2.9
130	428.7	3.3

COAST

GROWTH TYPE H, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	5.0	0.0
60	16.7	0.3
70	41.5	0.6
80	86.5	1.1
90	151.9	1.7
100	231.6	2.3
110	317.7	2.9
120	403.6	3.4
130	485.5	3.7

COAST

GROWTH TYPE H, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	1.5	0.0
50	3.4	0.0
60	13.6	0.2
70	35.1	0.5
90	75.7	0.9
90	137.4	1.5
100	215.0	2.1
110	300.3	2.7
120	386.6	3.2
130	469.5	3.6

COAST

GROWTH TYPE I, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	9.8	0.2
60	56.1	0.9
70	147.8	2.1
80	271.8	3.4
90	408.2	4.5
100	540.6	5.4
110	659.2	6.0
120	760.1	6.3
130	842.9	6.5

COAST

GROWTH TYPE I, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	15.0	0.3
70	71.0	1.0
80	170.6	2.1
90	298.7	3.3
100	435.4	4.4
110	565.6	5.1
120	680.9	5.7
130	778.0	6.0

COAST

GROWTH TYPE I, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.6	0.1
70	49.4	0.7
80	136.9	1.7
90	259.5	2.9
100	394.6	3.9
110	527.9	4.8
120	648.1	5.4
130	750.2	5.8

COAST

GROWTH TYPE I, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	12.4	0.2
60	63.3	1.1
70	159.0	2.3
80	285.2	3.6
90	421.9	4.7
100	553.2	5.5
110	670.1	6.1
120	769.1	6.4
130	850.2	6.5

COAST

GROWTH TYPE I, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	12.4	0.2
60	63.3	1.1
70	159.0	2.3
80	285.2	3.6
90	421.9	4.7
100	553.2	5.5
110	670.1	6.1
120	769.1	6.4
130	850.2	6.5

COAST

GROWTH TYPE I, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.3	0.0
60	31.6	0.5
70	88.5	1.3
80	157.4	2.1
90	255.4	2.9
100	341.6	3.4
110	419.4	3.8
120	485.9	4.0
130	540.8	4.2

COAST

GROWTH TYPE I, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.5	0.1
70	40.7	0.6
80	102.9	1.3
90	184.7	2.1
100	273.0	2.7
110	353.0	3.3
120	433.6	3.6
130	497.8	3.[illegible]

COAST

GROWTH TYPE I, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	3.1	0.0
70	27.5	0.4
80	91.6	1.0
90	158.9	1.8
100	246.5	2.5
110	333.3	3.0
120	412.1	3.4
130	479.8	3.7

COAST

GROWTH TYPE I, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	5.8	0.1
60	36.0	0.6
70	95.6	1.4
80	176.0	2.2
90	264.2	2.9
100	349.8	3.5
110	426.5	3.9
120	491.9	4.1
130	545.7	4.2

COAST

GROWTH TYPE I, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	5.8	0.1
60	36.0	0.6
70	95.6	1.4
80	176.0	2.2
90	264.2	2.9
100	349.8	3.5
110	426.5	3.9
120	491.9	4.1
130	545.7	4.2

COAST

GROWTH TYPE J, NORTH ASPECT

GOOD SITE

Age	**Volume (m^3/ha)**	**Mean Annual Increment**
10		
20		
30		
40		
50	9.8	0.2
60	56.1	0.9
70	147.8	2.1
80	271.8	3.4
90	406.2	4.5
100	540.6	5.4
110	659.2	6.0
120	760.1	6.3
130	842.9	6.5

COAST

GROWTH TYPE J, SOUTH ASPECT

GOOD SITE

Age	**Volume (m^3/ha)**	**Mean Annual Increment**
10		
20		
30		
40		
50	0.2	0.0
60	15.5	0.3
70	71.0	1.0
80	170.6	2.1
90	298.7	3.3
100	435.4	4.4
110	565.6	5.1
120	680.9	5.7
130	778.0	6.0

COAST

GROWTH TYPE J, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.6	0.1
70	49.4	0.7
80	136.8	1.7
90	258.5	2.9
100	394.6	3.9
110	527.9	4.8
120	648.1	5.4
130	750.8	5.8

COAST

GROWTH TYPE J, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	12.4	0.2
60	63.3	1.1
70	159.0	2.3
80	285.2	3.6
90	421.9	4.7
100	553.2	5.5
110	670.1	6.1
120	769.1	6.4
130	850.2	6.5

COAST

GROWTH TYPE J, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	12.4	0.2
60	63.3	1.1
70	159.0	2.3
80	295.2	3.6
90	421.9	4.7
100	553.2	5.5
110	670.1	6.1
120	769.1	6.4
130	850.2	6.5

COAST

GROWTH TYPE J, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.3	0.0
60	31.6	0.5
70	88.5	1.3
80	167.4	2.1
90	255.4	2.8
100	341.6	3.4
110	419.4	3.9
120	485.9	4.0
130	540.8	4.2

COAST

GROWTH TYPE J, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.5	0.1
70	40.7	0.6
80	102.9	1.3
90	184.7	2.1
100	273.0	2.7
110	358.0	3.3
120	433.6	3.6
130	497.8	3.8

COAST

GROWTH TYPE J, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment .
10		
20		
30		
40		
50		
60	3.1	0.0
70	27.5	0.4
80	81.6	1.0
90	155.9	1.8
100	246.5	2.5
110	333.3	3.0
120	412.1	3.4
130	479.8	3.7

COAST

GROWTH TYPE J, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	5.8	0.1
60	36.0	0.6
70	95.6	1.4
80	175.0	2.2
90	264.2	2.9
100	349.8	3.5
110	426.5	3.9
120	491.9	4.1
130	545.7	4.2

COAST

GROWTH TYPE J, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	5.8	0.1
60	36.0	0.6
70	95.6	1.4
80	175.0	2.2
90	264.2	2.9
100	349.8	3.5
110	426.5	3.9
120	491.9	4.1
130	545.7	4.2

COAST

GROWTH TYPE K, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	9.8	0.2
60	56.1	0.9
70	147.8	2.1
80	271.8	3.4
90	408.2	4.5
100	540.6	5.4
110	659.2	6.0
120	760.1	6.3
130	842.9	6.5

COAST

GROWTH TYPE K, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	0.2	0.0
60	15.5	0.3
70	71.0	1.0
80	170.6	2.1
90	298.7	3.3
100	435.4	4.4
110	565.6	5.1
120	680.9	5.7
130	778.0	6.0

COAST

GROWTH TYPE K, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.6	0.1
70	49.4	0.7
80	136.9	1.7
90	258.5	2.9
100	394.6	3.9
110	527.9	4.8
120	648.1	5.4
130	750.8	5.8

COAST

GROWTH TYPE K, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	12.4	0.2
60	63.3	1.1
70	159.0	2.3
80	285.2	3.6
90	421.9	4.7
100	553.2	5.5
110	670.1	6.1
120	765.1	6.4
130	850.2	6.5

COAST

GROWTH TYPE K, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	12.4	0.2
60	63.3	1.1
70	159.0	2.3
80	285.2	3.6
90	421.9	4.7
100	553.2	5.5
110	670.1	6.1
120	769.1	6.4
130	850.2	6.5

COAST

GROWTH TYPE K, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.3	0.0
60	31.6	0.5
70	88.5	1.3
80	167.4	2.1
90	255.4	2.8
100	341.6	3.4
110	419.4	3.8
120	485.9	4.0
130	540.8	4.2

COAST

GROWTH TYPE K, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.5	0.1
70	40.7	0.6
80	102.9	1.3
90	184.7	2.1
100	273.0	2.7
110	358.0	3.3
120	433.6	3.6
130	497.8	3.8

COAST

GROWTH TYPE K, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	3.1	0.0
70	27.5	0.4
80	91.6	1.0
90	159.9	1.8
100	246.5	2.5
110	333.3	3.0
120	412.1	3.4
130	479.8	3.7

COAST

GROWTH TYPE K, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	5.8	0.1
60	36.0	0.6
70	95.6	1.4
80	176.0	2.2
90	264.2	2.9
100	349.8	3.5
110	426.5	3.9
120	491.9	4.1
130	545.7	4.2

COAST

GROWTH TYPE K, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	5.8	0.1
60	36.0	0.6
70	95.6	1.4
80	176.0	2.2
90	264.2	2.9
100	349.8	3.5
110	426.5	3.9
120	491.9	4.1
130	545.7	4.2

APPENDIX 3

YIELD TABLES FOR UNTREATED BACKLOG LAND

INTERIOR B.C.

Ten tables are presented for each forest type in each appendix. There are two tables each for north, south, east, west and flat aspects. Each forest type/aspect combination has one table for good site and one for medium.

YIELD TABLES FOR UNTREATED BACKLOG LAND

The yield tables in Appendices 2 and 3 represent the yields expected from untreated backlog forest land. Appendix 2 contains tables for coastal B.C. Appendix 3 contains tables for the interior. The forest types are those defined by the B.C. Ministry of Forests and Lands in Table 1.

Table 1. Forest Types

LETTER CODE	INVENTORY TYPE GROUPS
A	FPL, FDecid, Pw (coast), F
B	FC, FCy, FH, FS
C	FPL, FDecid (interior), FPy, Py, Pa
D	Pw (interior), FL, LF, L
E	C, CF, CH
F	H, HPL, HDecid
G	HF, HC, HB, HS
H	B, BH, BS
I	S
J	SF, SH, SC, SB
K	SPL, SDecid
L	PL
M	PLF, PLS, PLB
N	PLDecid

Age in the yield tables means years after logging. Volume is volume per hectare net decay only. Minimum dbh is 22.5 cm for the coastal tables and 17.5 cm for the interior. Stump height is 30 cm and top diameter inside bark is 10 cm. The yields in each table are combinations of several MOFL Ek-Payandeh functions modified for backlog regeneration delays and levels of stocking. The site index reference heights for the species in each growth type are presented in Table 10 of the main report.

INTERIOR

GROWTH TYPE B, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.8	0.0
60	21.3	0.4
70	50.3	0.7
80	90.2	1.1
90	135.7	1.5
100	181.8	1.8
110	225.0	2.0
120	263.7	2.2
130	297.5	2.3

INTERIOR

GROWTH TYPE B, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	0.5	0.0
60	11.6	0.2
70	34.3	0.5
80	69.2	0.9
90	112.6	1.3
100	159.0	1.6
110	203.9	1.9
120	245.0	2.0
130	281.2	2.2

INTERIOR

GROWTH TYPE B, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	10.1	0.1
90	31.4	0.3
100	65.2	0.7
110	108.0	1.0
120	154.3	1.3
130	199.6	1.5

INTERIOR

GROWTH TYPE B, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	2.8	0.0
60	17.1	0.3
70	43.5	0.6
80	81.6	1.0
90	126.4	1.4
100	172.8	1.7
110	216.7	2.0
120	256.4	2.1
130	291.2	2.2

INTERIOR

GROWTH TYPE B, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.2	0.1
70	26.1	0.4
80	57.6	0.7
90	99.0	1.1
100	145.1	1.5
110	190.8	1.7
120	233.1	1.9
130	270.9	2.1

INTERIOR

GROWTH TYPE B, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.8	0.1
70	24.6	0.4
80	49.2	0.6
90	78.8	0.9
100	109.6	1.1
110	139.1	1.3
120	165.9	1.4
130	189.6	1.5

INTERIOR

GROWTH TYPE B, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.7	0.0
70	15.1	0.2
80	36.1	0.5
90	63.7	0.7
100	94.3	0.9
110	124.7	1.1
120	152.9	1.3
130	178.1	1.4

INTERIOR

GROWTH TYPE B, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	1.8	0.0
90	13.5	0.1
100	33.6	0.3
110	60.7	0.6
120	91.2	0.8
130	121.7	0.9

INTERIOR

GROWTH TYPE B, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	5.5	0.0
70	20.5	0.3
80	43.8	0.5
90	72.7	0.8
100	103.5	1.0
110	133.4	1.2
120	160.8	1.3
130	185.1	1.4

INTERIOR

GROWTH TYPE B, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.4	0.0
70	10.5	0.1
80	28.9	0.4
90	54.9	0.6
100	85.0	0.8
110	115.7	1.1
120	144.7	1.2
130	170.9	1.3

INTERIOR

GROWTH TYPE C, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	1.7	0.0
70	17.6	0.3
80	48.4	0.6
90	90.1	1.0
100	134.8	1.3
110	176.7	1.6
120	213.1	1.8
130	243.6	1.9

INTERIOR

GROWTH TYPE C, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	6.4	0.1
70	28.2	0.4
80	64.2	0.8
90	108.0	1.2
100	152.1	1.5
110	192.0	1.7
120	226.0	1.9
130	254.3	2.0

INTERIOR

GROWTH TYPE C, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.8	0.0
70	15.4	0.2
80	44.7	0.6
90	85.6	1.0
100	130.4	1.3
110	172.7	1.6
120	209.7	1.7
130	240.8	1.9

INTERIOR

GROWTH TYPE C, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	9.6	0.2
70	34.4	0.5
80	72.6	0.9
90	117.0	1.3
100	160.5	1.6
110	199.2	1.8
120	232.1	1.9
130	259.3	2.0

INTERIOR

GROWTH TYPE C, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	6.4	0.1
70	28.2	0.4
80	64.2	0.8
90	109.0	1.2
100	152.1	1.5
110	192.0	1.7
120	226.0	1.9
130	254.3	2.0

INTERIOR

GROWTH TYPE C, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	8.0	0.1
80	28.0	0.4
90	55.9	0.6
100	86.7	0.9
110	116.2	1.1
120	142.3	1.2
130	164.5	1.3

INTERIOR

GROWTH TYPE C, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.6	0.0
70	14.9	0.2
80	38.5	0.5
90	68.2	0.8
100	98.8	1.0
110	127.1	1.2
120	151.7	1.3
130	172.3	1.3

INTERIOR

GROWTH TYPE C, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	6.6	0.0
80	25.6	0.3
90	52.9	0.6
100	83.6	0.8
110	113.4	1.0
120	139.9	1.2
130	162.5	1.2

INTERIOR

GROWTH TYPE C, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.7	0.0
70	19.9	0.3
80	44.1	0.6
90	74.4	0.8
100	104.7	1.0
110	132.3	1.2
120	156.1	1.3
130	176.0	1.4

INTERIOR

GROWTH TYPE C, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.6	0.0
70	14.9	0.2
80	38.5	0.5
90	68.2	0.8
100	98.8	1.0
110	127.1	1.2
120	151.7	1.3
130	172.3	1.3

INTERIOR

GROWTH TYPE D, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	5.7	0.0
90	60.4	0.7
100	176.7	1.8
110	288.9	2.6
120	362.6	3.0
130	403.1	3.1

INTERIOR

GROWTH TYPE D, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	0.4	0.0
80	18.4	0.2
90	102.8	1.1
100	225.3	2.3
110	323.2	2.9
120	382.0	3.2
130	413.2	3.2

INTERIOR

GROWTH TYPE D, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	4.0	0.0
90	51.4	0.6
100	164.1	1.6
110	279.3	2.5
120	356.9	3.0
130	400.2	3.1

INTERIOR

GROWTH TYPE D, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	1.1	0.0
80	29.1	0.4
90	126.7	1.4
100	248.0	2.5
110	337.8	3.1
120	390.0	3.2
130	417.3	3.2

INTERIOR

GROWTH TYPE D, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	0.4	0.0
80	18.4	0.2
90	102.8	1.1
100	225.3	2.3
110	323.2	2.9
120	382.0	3.2
130	413.2	3.2

INTERIOR

GROWTH TYPE D, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	3.2	0.0
90	33.9	0.4
100	101.1	1.0
110	169.2	1.5
120	217.3	1.8
130	246.7	1.9

INTERIOR

GROWTH TYPE D, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	0.2	0.0
80	10.3	0.1
90	58.1	0.6
100	130.1	1.3
110	191.0	1.7
120	230.9	1.9
130	254.9	2.0

INTERIOR

GROWTH TYPE D, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	2.2	0.0
90	28.8	0.3
100	93.7	0.9
110	163.2	1.5
120	213.4	1.8
130	244.4	1.9

INTERIOR

GROWTH TYPE D, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	0.6	0.0
80	16.3	0.2
90	71.9	0.8
100	143.9	1.4
110	200.6	1.8
120	236.7	2.0
130	258.3	2.0

INTERIOR

GROWTH TYPE D, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	0.2	0.0
80	10.3	0.1
90	58.1	0.6
100	130.1	1.3
110	191.0	1.7
120	230.9	1.9
130	254.9	2.0

INTERIOR

GROWTH TYPE E, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	3.8	0.0
60	15.3	0.3
70	33.2	0.5
80	57.5	0.7
90	87.9	1.0
100	123.5	1.2
110	162.9	1.5
120	205.0	1.7
130	248.7	1.9

INTERIOR

GROWTH TYPE E, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	2.2	0.0
60	12.5	0.2
70	29.1	0.4
80	52.2	0.7
90	81.4	0.9
100	116.0	1.2
110	154.8	1.4
120	196.4	1.6
130	239.9	1.8

INTERIOR

GROWTH TYPE E, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.6	0.1
70	21.6	0.3
80	42.1	0.5
90	69.0	0.8
100	101.6	1.0
110	138.8	1.3
120	179.5	1.5
130	222.4	1.7

INTERIOR

GROWTH TYPE E, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.6	0.0
60	16.8	0.3
70	35.3	0.5
80	60.3	0.8
90	91.3	1.0
100	127.3	1.3
110	167.0	1.5
120	209.3	1.7
130.	253.1	1.9

INTERIOR

GROWTH TYPE E, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	4.6	0.0
60	16.8	0.3
70	35.3	0.5
80	60.3	0.8
90	91.3	1.0
100	127.3	1.3
110	167.0	1.5
120	209.3	1.7
130	253.1	1.9

INTERIOR

GROWTH TYPE E, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.5	0.1
70	19.6	0.3
80	36.5	0.5
90	57.8	0.6
100	83.0	0.8
110	111.3	1.0
120	141.7	1.2
130	173.4	1.3

INTERIOR
GROWTH TYPE E, SOUTH ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	5.6	0.0
70	16.8	0.2
80	32.7	0.4
90	53.2	0.6
100	77.7	0.8
110	105.4	1.0
120	135.5	1.1
130	167.0	1.3

INTERIOR
GROWTH TYPE E, EAST ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.5	0.0
70	11.8	0.2
90	25.8	0.3
90	44.5	0.5
100	67.5	0.7
110	94.0	0.9
120	123.2	1.0
130	154.2	1.2

INTERIOR

GROWTH TYPE E, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	0.6	0.0
60	8.5	0.1
70	21.1	0.3
80	38.4	0.5
90	60.2	0.7
100	85.7	0.9
110	114.2	1.0
120	144.8	1.2
130	176.6	1.4

INTERIOR

GROWTH TYPE E, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	0.6	0.0
60	8.5	0.1
70	21.1	0.3
80	38.4	0.5
90	60.2	0.7
100	85.7	0.9
110	114.2	1.0
120	144.8	1.2
130	176.6	1.4

INTERIOR

GROWTH TYPE F, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	3.3	0.0
50	12.6	0.3
60	30.4	0.5
70	56.9	0.8
80	91.2	1.1
90	131.8	1.5
100	176.8	1.8
110	224.6	2.0
120	273.6	2.3
130	322.8	2.5

INTERIOR

GROWTH TYPE F, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	2.3	0.0
50	10.1	0.2
60	26.1	0.4
70	50.9	0.7
80	83.8	1.0
90	123.3	1.4
100	167.5	1.7
110	214.9	2.0
120	263.8	2.2
130	313.0	2.4

INTERIOR

GROWTH TYPE F, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.3	0.0
70	3.9	0.0
80	14.0	0.2
90	32.6	0.4
100	60.0	0.6
110	95.0	0.9
120	136.1	1.1
130	181.5	1.4

INTERIOR

GROWTH TYPE F, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.2	0.0
50	1.9	0.0
60	9.0	0.2
70	24.1	0.3
80	48.0	0.6
90	80.2	0.9
100	119.1	1.2
110	163.0	1.5
120	210.1	1.8
130	258.9	2.0

INTERIOR

GROWTH TYPE F, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	2.8	0.0
50	11.3	0.2
60	28.2	0.5
70	53.9	0.8
80	87.5	1.1
90	127.5	1.4
100	172.2	1.7
110	219.7	2.0
120	268.7	2.2
130	317.9	2.4

INTERIOR

GROWTH TYPE F, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.3	0.0
50	3.9	0.0
60	13.5	0.2
70	30.0	0.4
80	52.7	0.7
90	80.8	0.9
100	112.8	1.1
110	147.4	1.3
120	183.5	1.5
130	220.2	1.7

INTERIOR

GROWTH TYPE F, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	2.7	0.0
60	11.0	0.2
70	26.1	0.4
80	47.7	0.6
90	74.8	0.8
100	106.1	1.1
110	140.3	1.3
120	176.2	1.5
130	212.8	1.6

INTERIOR

GROWTH TYPE F, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	0.4	0.0
80	4.6	0.0
90	14.9	0.2
100	32.0	0.3
110	55.3	0.5
120	83.8	0.7
130	116.1	0.9

INTERIOR
GROWTH TYPE F, WEST ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.3	0.0
70	9.9	0.1
80	24.3	0.3
90	45.3	0.5
100	71.9	0.7
110	102.8	0.9
120	136.8	1.1
130	172.6	1.3

INTERIOR
GROWTH TYPE F, FLAT ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.2	0.0
50	3.3	0.0
60	12.2	0.2
70	28.0	0.4
80	50.2	0.6
90	77.8	0.9
100	109.4	1.1
110	143.8	1.3
120	179.9	1.5
130	216.5	1.7

INTERIOR

GROWTH TYPE G, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	1.2	0.0
50	7.3	0.1
60	20.8	0.3
70	42.4	0.6
80	72.0	0.9
90	108.6	1.2
100	150.5	1.5
110	196.3	1.8
120	244.4	2.0
130	293.5	2.3

INTERIOR

GROWTH TYPE G, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	1.5	0.0
80	8.3	0.1
90	22.6	0.3
100	45.0	0.5
110	75.4	0.7
120	112.5	0.9
130	155.0	1.2

INTERIOR

GROWTH TYPE G, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	0.4	0.0
60	4.8	0.0
70	15.9	0.2
80	35.1	0.4
90	62.4	0.7
100	97.0	1.0
110	137.5	1.2
120	182.3	1.5
130	229.8	1.8

INTERIOR

GROWTH TYPE G, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.9	0.0
50	6.4	0.1
60	19.1	0.3
70	39.9	0.6
80	68.7	0.9
90	104.6	1.2
100	146.1	1.5
110	191.6	1.7
120	239.5	2.0
130	288.6	2.2

INTERIOR
GROWTH TYPE G, SOUTH ASPECT
GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	0.6	0.0
50	5.6	0.1
60	17.4	0.3
70	37.4	0.5
80	65.5	0.8
90	100.8	1.1
100	141.8	1.4
110	186.9	1.7
120	234.7	2.0
130	283.6	2.2

INTERIOR
GROWTH TYPE G, NORTH ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	3.8	0.0
60	13.0	0.2
70	28.3	0.4
80	49.3	0.6
90	75.5	0.8
100	105.7	1.1
110	138.8	1.3
120	173.8	1.4
130	209.6	1.6

INTERIOR
GROWTH TYPE G, EAST ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	0.2	0.0
80	4.5	0.0
90	14.3	0.2
100	30.1	0.3
110	51.7	0.5
120	78.3	0.7
130	108.9	0.8

INTERIOR
GROWTH TYPE G, WEST ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.2	0.0
70	9.6	0.1
80	23.1	0.3
90	42.4	0.5
100	67.2	0.7
110	96.3	0.9
120	128.7	1.1
130	163.1	1.3

INTERIOR

GROWTH TYPE G, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	3.2	0.0
60	11.8	0.2
70	26.5	0.4
80	47.0	0.6
90	72.7	0.8
100	102.5	1.0
110	135.4	1.2
120	170.2	1.4
130	206.0	1.6

INTERIOR

GROWTH TYPE G, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	2.7	0.0
60	10.7	0.2
70	24.7	0.4
80	44.7	0.6
90	69.9	0.8
100	99.4	1.0
110	132.0	1.2
120	166.7	1.4
130	202.4	1.6

INTERIOR

GROWTH TYPE H, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	2.0	0.0
80	16.3	0.2
90	37.0	0.4
100	69.4	0.7
110	115.6	1.1
120	167.6	1.4
130	217.5	1.7

INTERIOR

GROWTH TYPE H, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.0	0.0
70	16.3	0.2
80	37.0	0.5
90	69.4	0.8
100	115.6	1.2
110	167.6	1.5
120	217.5	1.8
130	262.7	2.0

INTERIOR

GROWTH TYPE H, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	4.6	0.0
70	19.8	0.3
80	42.3	0.5
90	77.7	0.9
100	125.9	1.3
110	177.9	1.6
120	227.0	1.9
130	271.1	2.1

INTERIOR

GROWTH TYPE H, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	0.7	0.0
60	14.6	0.2
70	34.5	0.5
80	65.5	0.8
90	110.6	1.2
100	162.4	1.6
110	212.7	1.9
120	258.4	2.2
130	299.0	2.3

INTERIOR

GROWTH TYPE H, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	11.5	0.2
70	29.9	0.4
80	58.1	0.7
90	100.7	1.1
100	152.0	1.5
110	203.0	1.8
120	249.7	2.1
130	291.3	2.2

INTERIOR

GROWTH TYPE H, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	6.3	0.0
90	17.9	0.2
100	31.5	0.3
110	50.7	0.5
120	78.4	0.7
130	110.1	0.8

INTERIOR

GROWTH TYPE H, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	6.3	0.0
80	17.9	0.2
90	31.5	0.4
100	50.7	0.5
110	78.4	0.7
120	110.1	0.9
130	141.5	1.1

INTERIOR

GROWTH TYPE H, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	8.4	0.1
80	20.5	0.3
90	34.7	0.4
100	55.7	0.6
110	84.6	0.8
120	116.5	1.0
130	147.5	1.1

INTERIOR

GROWTH TYPE H, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	5.3	0.0
70	16.7	0.2
80	30.0	0.4
90	48.4	0.5
100	75.4	0.8
110	106.9	1.0
120	138.4	1.2
130	167.7	1.3

INTERIOR

GROWTH TYPE H, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	3.4	0.0
70	14.2	0.2
80	27.2	0.3
90	44.0	0.5
100	69.4	0.7
110	100.5	0.9
120	132.3	1.1
130	162.1	1.2

INTERIOR

GROWTH TYPE I, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	11.9	0.2
70	30.0	0.4
80	64.2	0.8
90	102.9	1.1
100	144.1	1.4
110	185.3	1.7
120	225.1	1.9
130	262.7	2.0

INTERIOR

GROWTH TYPE I, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	36.5	0.5
90	71.6	0.8
100	111.1	1.1
110	152.4	1.4
120	193.4	1.6
130	232.8	1.8

INTERIOR

GROWTH TYPE I, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	6.9	0.0
80	26.8	0.3
90	60.6	0.7
100	98.9	1.0
110	139.9	1.3
120	181.2	1.5
130	221.2	1.7

INTERIOR

GROWTH TYPE I, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	19.8	0.3
70	33.3	0.5
80	67.9	0.8
90	107.0	1.2
100	148.2	1.5
110	189.3	1.7
120	229.0	1.9
130	266.3	2.0

INTERIOR

GROWTH TYPE I, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	19.8	0.3
70	33.3	0.5
80	67.9	0.8
90	107.0	1.2
100	148.2	1.5
110	189.3	1.7
120	229.0	1.9
130	266.3	2.0

INTERIOR

GROWTH TYPE I, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	8.0	0.1
80	24.8	0.3
90	47.4	0.5
100	74.1	0.7
110	103.1	0.9
120	132.7	1.1
130	161.7	1.2

INTERIOR

GROWTH TYPE I, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	10.9	0.1
90	28.9	0.3
100	52.4	0.5
110	79.8	0.7
120	109.0	0.9
130	138.5	1.1

INTERIOR

GROWTH TYPE I, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	6.6	0.0
90	22.9	0.3
100	44.9	0.4
110	71.3	0.6
120	100.1	0.8
130	129.7	1.0

INTERIOR

GROWTH TYPE I, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	9.4	0.1
80	26.8	0.3
90	49.9	0.6
100	76.9	0.8
110	106.0	1.0
120	135.6	1.1
130	164.5	1.3

INTERIOR

GROWTH TYPE I, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	9.4	0.1
80	26.8	0.3
90	49.9	0.6
100	76.9	0.8
110	106.0	1.0
120	135.6	1.1
130	164.5	1.3

INTERIOR

GROWTH TYPE J, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	2.9	0.0
60	14.7	0.2
70	33.7	0.5
80	60.7	0.8
90	95.7	1.1
100	136.6	1.4
110	179.3	1.6
120	220.2	1.8
130	257.7	2.0

INTERIOR

GROWTH TYPE J, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	10.4	0.2
70	27.2	0.4
80	51.7	0.6
90	84.5	0.9
100	124.0	1.2
110	166.5	1.5
120	208.2	1.7
130	246.9	1.9

INTERIOR

GROWTH TYPE J, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	6.7	0.1
70	21.4	0.3
80	43.5	0.5
90	73.8	0.8
100	111.6	1.1
110	153.7	1.4
120	196.0	1.6
130	235.7	1.8

INTERIOR

GROWTH TYPE J, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.9	0.1
70	23.3	0.3
80	46.2	0.6
90	77.3	0.9
100	115.7	1.2
110	158.0	1.4
120	200.1	1.7
130	239.5	1.8

INTERIOR

GROWTH TYPE J, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	1.4	0.0
60	11.7	0.2
70	29.3	0.4
80	54.6	0.7
90	68.2	1.0
100	128.2	1.3
110	170.8	1.6
120	212.3	1.8
130	250.5	1.9

INTERIOR

GROWTH TYPE J, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.2	0.0
70	9.7	0.1
80	22.0	0.3
90	40.9	0.5
100	66.1	0.7
110	95.0	0.9
120	124.7	1.0
130	153.3	1.2

INTERIOR
GROWTH TYPE J, SOUTH ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.7	0.0
70	7.0	0.0
80	17.7	0.2
90	34.5	0.4
100	58.0	0.6
110	86.1	0.8
120	115.8	1.0
130	144.9	1.1

INTERIOR
GROWTH TYPE J, EAST ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	4.7	0.0
80	13.9	0.2
90	28.8	0.3
100	50.3	0.5
110	77.3	0.7
120	106.9	0.9
130	136.4	1.0

INTERIOR

GROWTH TYPE J, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	5.4	0.0
80	15.1	0.2
90	30.6	0.3
100	52.8	0.5
110	80.2	0.7
120	109.9	0.9
130	139.2	1.1

INTERIOR

GROWTH TYPE J, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	1.2	0.0
70	7.8	0.1
80	19.1	0.2
90	36.6	0.4
100	60.6	0.6
110	89.0	0.8
120	118.8	1.0
130	147.8	1.1

INTERIOR

GROWTH TYPE K, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	3.3	0.0
70	22.1	0.3
80	53.1	0.7
90	94.1	1.0
100	140.6	1.4
110	188.3	1.7
120	234.3	2.0
130	276.9	2.1

INTERIOR

GROWTH TYPE K, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	15.2	0.2
80	42.6	0.5
90	81.0	0.9
100	126.3	1.3
110	174.0	1.6
120	220.8	1.8
130	264.5	2.0

INTERIOR

GROWTH TYPE K, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	9.5	0.1
80	33.1	0.4
90	68.5	0.8
100	112.3	1.1
110	159.7	1.5
120	207.0	1.7
130	251.8	1.9

INTERIOR

GROWTH TYPE K, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	11.3	0.2
80	36.1	0.5
90	72.6	0.8
100	116.9	1.2
110	164.5	1.5
120	211.6	1.8
130	256.1	2.0

INTERIOR

GROWTH TYPE K, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	9.5	0.2
70	33.1	0.5
80	68.5	0.9
90	112.3	1.2
100	159.7	1.6
110	207.0	1.9
120	251.8	2.1
130	292.8	2.3

INTERIOR

GROWTH TYPE K, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	5.8	0.0
80	19.5	0.2
90	41.8	0.5
100	70.7	0.7
110	103.5	0.9
120	137.4	1.1
130	170.2	1.3

INTERIOR

GROWTH TYPE K, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	3.3	0.0
80	14.5	0.2
90	34.3	0.4
100	61.5	0.6
110	93.5	0.8
120	127.2	1.1
130	160.6	1.2

INTERIOR

GROWTH TYPE K, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	1.4	0.0
80	10.2	0.1
90	27.4	0.3
100	52.7	0.5
110	83.6	0.8
120	117.1	1.0
130	150.7	1.2

INTERIOR
GROWTH TYPE K, WEST ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	2.0	0.0
80	11.6	0.1
90	29.6	0.3
100	55.6	0.6
110	86.9	0.8
120	120.5	1.0
130	154.0	1.2

INTERIOR
GROWTH TYPE K, FLAT ASPECT
MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	1.4	0.0
70	10.2	0.1
80	27.4	0.3
90	52.7	0.6
100	83.6	0.8
110	117.1	1.1
120	150.7	1.3
130	182.8	1.4

INTERIOR

GROWTH TYPE L, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	9.4	0.2
70	30.1	0.4
80	59.3	0.7
90	94.6	1.1
100	133.2	1.3
110	172.6	1.6
120	211.2	1.8
130	248.0	1.9

INTERIOR

GROWTH TYPE L, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40	2.1	0.0
50	0.9	0.0
60	16.6	0.3
70	40.9	0.6
80	72.9	0.9
90	109.8	1.2
100	148.9	1.5
110	188.2	1.7
120	226.2	1.9
130	262.0	2.0

INTERIOR

GROWTH TYPE L, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	7.8	0.1
70	27.6	0.4
80	56.1	0.7
90	90.9	1.0
100	129.3	1.3
110	168.7	1.5
120	207.4	1.7
130	244.4	1.9

INTERIOR

GROWTH TYPE L, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	20.7	0.3
70	46.8	0.7
80	80.0	1.0
90	117.5	1.3
100	156.8	1.6
110	195.9	1.8
120	233.5	1.9
130	268.9	2.1

INTERIOR

GROWTH TYPE L, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	16.6	0.3
70	40.9	0.6
80	72.9	0.9
90	109.8	1.2
100	148.9	1.5
110	188.2	1.7
120	226.2	1.9
130	262.0	2.0

INTERIOR

GROWTH TYPE L, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.6	0.0
70	8.1	0.1
80	21.7	0.3
90	40.3	0.4
100	62.2	0.6
110	85.8	0.8
120	109.8	0.9
130	133.2	1.0

INTERIOR

GROWTH TYPE L, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.8	0.0
70	12.8	0.2
80	28.6	0.4
90	48.7	0.5
100	71.5	0.7
110	95.4	0.9
120	119.3	1.0
130	142.3	1.1

INTERIOR

GROWTH TYPE L, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.2	0.0
70	7.1	0.1
80	20.1	0.3
90	38.2	0.4
100	59.9	0.6
110	83.4	0.8
120	107.4	0.9
130	130.9	1.0

INTERIOR

GROWTH TYPE L, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	4.3	0.0
70	15.6	0.2
80	32.3	0.4
90	53.1	0.6
100	76.2	0.8
110	100.2	0.9
120	124.0	1.0
130	146.8	1.1

INTERIOR

GROWTH TYPE L, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.8	0.0
70	12.8	0.2
80	28.6	0.4
90	48.7	0.5
100	71.5	0.7
110	95.4	0.9
120	119.3	1.0
130	142.3	1.1

INTERIOR

GROWTH TYPE M, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90	13.9	0.2
100	33.7	0.3
110	55.7	0.5
120	78.5	0.7
130	101.1	0.8

INTERIOR

GROWTH TYPE M, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90	8.7	0.0
100	27.4	0.3
110	49.0	0.4
120	71.6	0.6
130	94.3	0.7

INTERIOR

GROWTH TYPE M, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90	12.1	0.1
100	31.6	0.3
110	53.5	0.5
120	76.2	0.6
130	98.8	0.8

INTERIOR

GROWTH TYPE M, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	7.1	0.0
90	25.4	0.3
100	46.7	0.5
110	69.3	0.6
120	92.1	0.8
130	114.4	0.9

INTERIOR

GROWTH TYPE M, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	4.0	0.0
90	21.4	0.2
100	42.3	0.4
110	64.8	0.6
120	87.6	0.7
130	110.0	0.8

INTERIOR

GROWTH TYPE M, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90		
100	6.8	0.0
110	21.8	0.2
120	38.0	0.3
130	54.5	0.4

INTERIOR

GROWTH TYPE H, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90		
100	2.8	0.0
110	17.1	0.2
120	33.0	0.3
130	49.5	0.4

INTERIOR

GROWTH TYPE H, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90		
100	5.5	0.0
110	20.2	0.2
120	36.3	0.3
130	52.8	0.4

INTERIOR

GROWTH TYPE M, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90	1.5	0.0
100	15.6	0.2
110	31.4	0.3
120	47.9	0.4
130	64.3	0.5

INTERIOR

GROWTH TYPE M, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80		
90		
100	12.6	0.1
110	28.2	0.3
120	44.6	0.4
130	61.0	0.5

INTERIOR

GROWTH TYPE 8, NORTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	0.2	0.0
60	6.0	0.1
70	21.3	0.3
80	47.1	0.6
90	79.4	0.9
100	114.2	1.1
110	148.9	1.4
120	182.3	1.5
130	213.8	1.6

INTERIOR

GROWTH TYPE 8, SOUTH ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	3.5	0.0
70	15.5	0.2
80	38.4	0.5
90	69.3	0.8
100	103.7	1.0
110	138.6	1.3
120	172.5	1.4
130	204.6	1.6

INTERIOR

GROWTH TYPE II, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	5.1	0.0
70	19.2	0.3
80	44.1	0.6
90	76.0	0.8
100	110.7	1.1
110	145.5	1.3
120	179.1	1.5
130	210.8	1.6

INTERIOR

GROWTH TYPE II, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	2.8	0.0
60	13.8	0.2
70	35.7	0.5
80	66.0	0.8
90	100.2	1.1
100	135.1	1.4
110	169.2	1.5
120	201.5	1.7
130	231.7	1.8

INTERIOR

GROWTH TYPE E, FLAT ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50	1.7	0.0
60	10.8	0.2
70	30.5	0.4
80	59.5	0.7
90	93.2	1.0
100	128.2	1.2
110	162.5	1.5
120	195.2	1.6
130	225.8	1.7

INTERIOR

GROWTH TYPE E, NORTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.8	0.0
70	7.9	0.1
80	21.8	0.3
90	40.8	0.5
100	62.3	0.6
110	84.5	0.8
120	106.3	0.9
130	127.1	1.0

INTERIOR

GROWTH TYPE B, SOUTH ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	5.0	0.0
80	17.0	0.2
90	34.8	0.4
100	55.8	0.6
110	77.8	0.7
120	99.8	0.8
130	121.0	0.9

INTERIOR

GROWTH TYPE B, EAST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	0.5	0.0
70	6.9	0.0
80	20.1	0.3
90	38.8	0.4
100	60.1	0.6
110	82.3	0.7
120	104.1	0.9
130	125.1	1.0

INTERIOR

GROWTH TYPE E, WEST ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	4.2	0.0
70	15.5	0.2
80	32.8	0.4
90	53.6	0.6
100	75.6	0.8
110	97.7	0.9
120	118.9	1.0
130	139.0	1.1

INTERIOR

GROWTH TYPE E, FLAT ASPECT

MEDIUM SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60	2.8	0.0
70	12.7	0.2
80	29.0	0.4
90	49.3	0.5
100	71.2	0.7
110	93.3	0.8
120	114.8	1.0
130	135.1	1.0

COAST

GROWTH TYPE F, EAST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70		
80	14.8	0.2
90	107.8	1.2
100	192.3	1.9
110	276.2	2.5
120	358.5	3.0
130	439.2	3.4

COAST

GROWTH TYPE F, WEST ASPECT

GOOD SITE

Age	Volume (m^3/ha)	Mean Annual Increment
10		
20		
30		
40		
50		
60		
70	73.2	1.0
80	158.6	2.0
90	242.8	2.7
100	325.8	3.3
110	406.7	3.7
120	484.2	4.0
130	559.2	4.3